Department of Civil and Structural Engineering

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A Study of Transportation Planning Model for Developing Area

By

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DECLARATION

I hereby declare that this thesis entitled **"A Study of Transportation Planning Model for Developing Area"** has not been, either in whole or in part, previously submitted for a degree in this or other institutions, and the work presented in this thesis is original unless otherwise acknowledged in the text.

SIGNED

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Hongyi WANG

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LIST OF PUBLICATIONS

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1. H.Y. Wang, W.G.Wong and W.T. Hung(1996), "Highway Development in the Pearl River Delta Region", Asia Engineers (The Journal of the Hong Kong Institute of Engineers), November 1996, pp.9-11

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Abstract of thesis entitled:

A Study of Transportation Planning Model for Developing Area

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ABSTRACT

Along with the rapid economic development in many developing countries such as P. R. China, the patterns of urban development have been greatly changed. To catch for this change, lots of transportation systems and traffic infrastructures are under planning and construction. However, investment decisions in the urban transportation sector in developing areas reflect more and more changing emphasis from purely technical and economic solutions to broader system planning approaches involving the various sectors of the government and the community and taking into account human, social, economic and environmental factors and goals. In order to make urban transport investments and policies in developing areas more effective, it is necessary to analysis and evaluate a wide range of alternative transport solutions before selecting those most adequate for detailed study. This thesis therefore presents some discussions about appraising and improving existing decision making tools available in the form of simplified traffic computer models.

This thesis focuses on the study of "strategic" models and provides information on the degree of simplification which is compatible with meaningful results. Many different mathematical models have been developed to represent the traffic conditions in urban areas. Such models normally consist of computer programmes which accept data describing a basic transport situation and hence may be used to estimate the effects on traffic of possible future changes. These models are simplified to the extent that they facilitate rapid analysis of many alternative

transport policies, but to serve this purpose it is also necessary in some instances to retain considerable detail in particular aspects of the conditions studied, such as the use of a particular mode of transport or the group of the population which benefits or pays for a particular change.

It should be recognised that models suitable for strategic studies have particular characteristics. The basic requirement is that large changes in transport systems can be dealt with and for this reason it is usually necessary to study the equilibrium between supply of transport (in terms of infrastructure and level of service) and the corresponding demand. It is also necessary to be able to study changes in land use and the distribution of various activities.

It is important that the correct balance is struck between expenditure on the collection of data and on modelling and analysis. This is assisted by the fact that equilibrium models provide specific information on the accuracy of their results.

The transferability of data from one city to another deserves further consideration and improved international accessibility of transportation study data through a form of data bank may be beneficial.

It should be emphasised that strategic transport planning models are in their infancy and it is clear that an important step towards making them more useful for policy decisions would be to have improved criteria to define the quality of existing and proposed transport systems and services. It would be desirable to include environmental factors in such criteria.

Finally, a practical strategic transport planning model has been put into use in the

RDS (Railway Development Study) Project in Shenzhen, some specific methodologies and evaluations are also presented in this thesis.

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INTRODUCTION

CHAPTER 1

INTRODUCTION

1.1 Statement of The Problem

Along with the rapid economic development in many developing countries such as P. R. China, the patterns of urban development have been greatly changed. To catch for this change and push up the socio-economic development of whole area, a lot of plans on transportation have also been conducted by the government and the community to determine the policies, investments and schemes of the transportation system and traffic infrastructures.

However, many experiences from transportation planning commenced in Beijing, Shanghai, Guangzhou, Shenzhen, which are biggest and most important cities in China, show that the conventional transport planning models developed by many developed countries in 1960's are not very effective and useful in these areas. That is because that there are great differences in urban development and transport conditions between developed areas and developing areas, which are mainly shown as below:

1) The increase rate of the population in developing areas is very sharp;

2) The change in pattern of land use is very quick;

3) In very short period, one territory could be developed from nothing to sub-

center of the area;

4) The lack of basic land use and traffic data for construction of the database. Some territories are even zero in last several years;

5) Most developing areas have no entire transport systems, like road network, mass rail network, suitable traffic management system, etc..

So, the transport planning authorities in developing areas need means of appraising possible investments or policies and finding out the main corridors for road network, mass rail network without detailed transportation studies of the classical type which involve the collection and analysis of large volumes of data and the running of complex and costly computer models. This process is unwieldy, inflexible and slow and it is not certain that the level of detail and accuracy is well matched to the planning phase concerned .

This situation has given rise to a number of "strategic" transport models which enable the users study a wide range of possible alternatives before picking the most likely ones for detailed study. Less affluent towns may limit their planning to the strategic level and it may be prepare a sufficient background of planning guidelines to minimize individual detailed studies in order to reach the required conclusions in some instances.

1.2 Objectives

1) To review the present state of development of urban transport models with particular reference to:

   - their complexity
   - their validity

2) To consider the minimum data required for an acceptable model both for present and future requirements;

3) To report on the existing urban transport models to real situations

4) To specify future research needs

1.3 Features of Strategic Models

1) The model should be suitable for strategic studies in that broad policy effects should be studied rather than detailed projects. Since results must be intelligible, the models must be clear and understandable and must be suitable for instructional use.

2) It should be possible to apply the models without expensive special-purpose (home interview) surveys. Particular attention should be paid to refurbishing or generalising existing data and the study of home-work trips only may suffice in some cases.

3) The period to be studied would range from the near future to, say, 15 years or more hence; models of a sector or subarea of the overall transport system

often deal with the shorter term predictions.

4) The relationships between model cost (and hence complexity) and the necessary and obtainable accuracy should be understood (developments in methodology have an important bearing on this) .

5) Clear and fully analysed results on a planning alternative should be available within a short time to permit the study of a wide variety of alternatives. The importance of effective and imaginative presentation of results should be emphasized.

The above points have been made on the overall understanding that the cost of this phase of modelling should be minimised and that there is a need for parallel activities on both strategic and detailed models, certainly for the larger urban areas, the strategic results being normally available first.

In the sector model mentioned in the third item above, interest may be directed towards a particular corridor of movement, a particular mode of travel, etc., narrowing the coverage of the model but perhaps incorporating considerable detail in the sphere of interest, for example with a view to studying the effect of adding a single new line of communication or new activity center to an existing situation.

Overall, Important features of strategic models should be the ability to communicate to those responsible for policy and administration such ideas as the link between future land use, residential density , employment , etc . and the need for commensurate transport infrastructure[4][5]. This is of critical importance in the case of the city center, and has to be viewed in the context of the potential growth in traffic.

The models should be easy to operate and therefore input data requirements must be limited and suitable for reliable extrapolation (e, g, population and employment densities), Too much refinement, such as coefficients resulting from multiple regressions, can be self defeating if they do not represent understandable phenomena[6].

The question of travel mode is fast becoming the key to urban transport problems, Most cities can envisage an adequate transport network if public transport service levels and patronage can be improved, In most cases this can be done with currently available hardware given improved infrastructure, particularly interchange facilities, and possibly some private transport restraint, However, the maintenance of off-peak services and high density peak requirements with increasing labor costs make more use of automatic systems attractive . Models are needed which will assist in the evaluation of these prospects.

The model types which have so far resulted from these common broad objectives are described in this report. These represent different choices in the degree of simplification which is adopted in the model components , Decisions are also necessary on time effects , both with regard to peak /off-peak conditions and as to whether the history of changes with time should be reproduced , the latter implying more complex modelling than would be appropriate for strategic studies by present methods .

Examples of strategic models described in this thesis represent various choices in the representation adopted in the components listed below :

1) The number and type of zones.

2) The population characteristics.

3) Trip generation factors, effects of land use and journey purpose.

4) The transport network, the balance between public and private transport facilities.

5) The modes of transport and factors affecting choice of mode.

6) The objective functions or definitions of utility and the evaluation process.

7) Travel decision criteria (including route and destination alternatives).

8) Environmental effects.

9) Social, commercial and political repercussions, impact on land use.

Chapter 2

LITERATURE REIVEW

CHAPTER 2

LITERATURE REVIEW

2.1 The Function of Models in Urban Planning

It is clear that the overall process must include examination of transport, environment and land use effects. Each of these requires models which permit a detailed examination of future situations to enable planners to choose the best overall compromise. The process involved is illustrated in Figure 2-1.

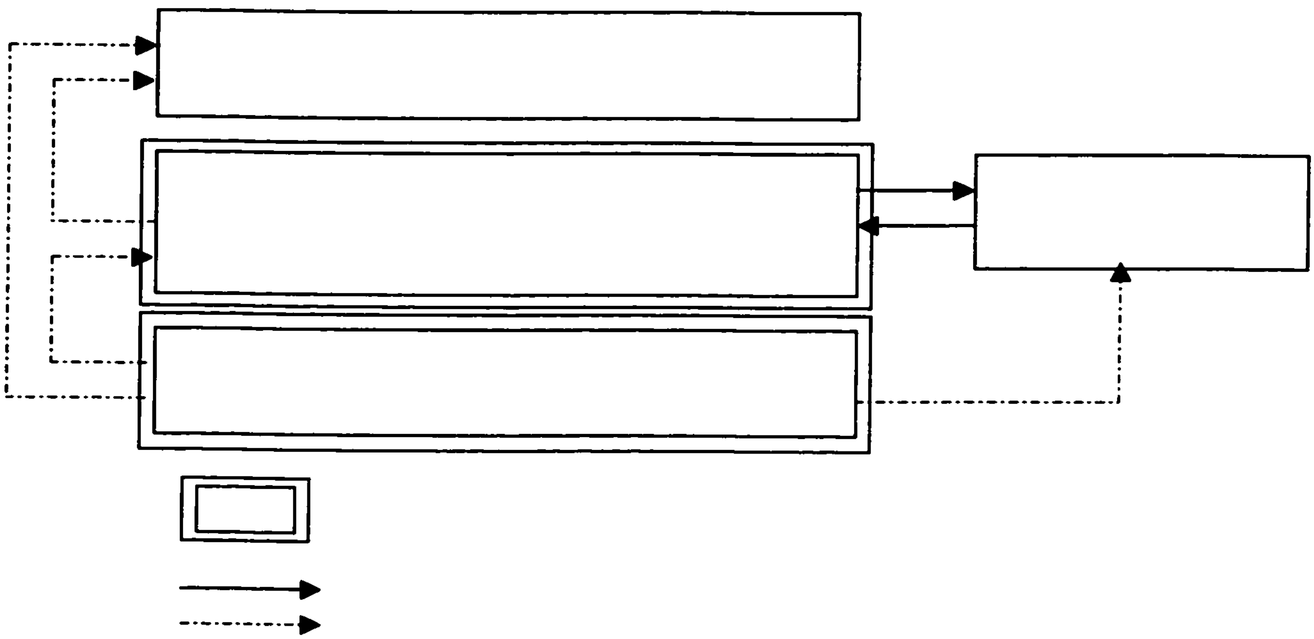

Figure 2-1 Role of Models in Planning Process

Environmental effects and social repercussions may perhaps be considered outside the sphere of traffic models. It is true that limited progress has been achieved in quantified modelling of such aspects but the importance of these questions demands that urban transport modelling must be adapted to be compatible with their evaluation and any long-term studies should have provision for outputs and inputs at the interface between traffic and social effects. There is, however, a considerable lack of understanding of the interaction between transport facilities and land use patterns. Practice at present relies upon a fixed land-use plan used as the input to a traffic study. An alternative land use plan may then be introduced for a repeat study. Clearly it is possible to examine only very few alternatives in this way.

The relevance of the traffic models considered below is an important aspect of their usefulness.

1) In practical terms, models have generally been used to calculate future traffic on the road network. This calculation shows the bottlenecks and gives an idea of where the road network should be improved.

2) In some cases several land-use and traffic plans are prepared at once , and traffic is calculated for all combinations of land-use and traffic plans . In other cases the first anticipated land-use plan gives rise to special traffic difficulties and a new land-use plan and traffic plan is prepared .

3) The calculation of the yearly traffic is also often used for a cost-benefit analysis of the different proposals. An other important use of the calculated future traffic is the setting up of priority programmes: when to build the various phases of the

proposed new roads .

Besides the comprehensive transport plans covering a whole city, the models are used for determining traffic effects of :

1) A new circumferential road ,

2) A new housing development

3) A new pedestrian street ,

4) New public transport alternatives .

Today many other kinds of issues are also being studied:

1) Policies to promote increased usage of a particular public transport line, e.g. by in creased parking charges or decreased public transport fares.

2) Policies to provide increased mobility for special groups of travelers, such as the elderly , young , handicapped , etc .

3) The location and design features of alternatives , such as highways , improved arterial streets , traffic management schemes , and parking policies , as well as public transport alternatives.

4) The effect of staggered working hours on street traffic.

5) The effect of traffic policies intending to reduce energy consumption, air pollution and noise.

6) The development of new public transport alternatives, e. g. dial-a-bus .

2.2 Summary of Transport Planning Models

An attempt has been made to assemble the types of model into a systematic summary. It is difficult to do this without an overwhelming amount of detail but Table 2-1 describes the leading particulars of interest.

2.3 Reviews of Existing Models

2.3.1 Introduction

This section indicates the current state of the art in urban traffic models, i. e. the four-step models conventionally used in urban transportation and the new single-step "explicit" demand models. This review is necessary in order to provide a background for the consideration of possible simplification methods.

The basic theory which underlies travel forecasting techniques will first be reviewed then, and used to show the relationships between the conventional models and the equilibrium models . The relationship of disaggregate and aggregate modelling approaches will be described. Mention will be made of urban dynamic development models..

Table 2-1 Summary of Urban Traffic Models

TYPE	PURPOSE	NETWORK	PERIOD (YRS)	AREA	INPUT DATA	BASIC STRUCTURE	USER CLASSIFICATIO N	NON-USER EFFECTS	OUTPUTS	CUSTOMER
(1) Detailed 4-atep e.g. SELNEC HRB TAP FABER	Overall Transport Planning	Geographic All main Routes	10-20	Conurbations and large towns	Home interviews Traffic surveys PT surveys Land use growth factors Generation assumptions	Generation Distrbution Mode split Assignment (capacity restraint) Evaluation	Car availability Trip purpose Time value	Model outputs suitable for environmental assessments	Traffic link Speeds and flows Mode patronage User benefits	Local Authorites
(2) Hierarchical e.g. SALTSFORD LINCOLN LTS ZONE 277	Evaluation Of major Planning Alternatives (strategic)	Geographicdet-ailed Surrounded By skeletal	10-20	Also smaller towns	Simplified trip matrix Traffic counts Generation assumption	As above but small no.of zones	Permits Aar/P.T. Aplit but User largely Aggregated	Results could provide background environment studies in chosen zone	Corridor Speeds and flows Broad P.T. Patronage Major effects on user benefits	Local Authorities Policy Studies
(3) Hierarchical e.g. SALTSFORD LINCOLN LTS ZONE 277	Detailed Study of Chosen small Area with Effect of Surrounding Network	Geometric Skeletal e.g. ring/radial	5-15	Smaller towns and chosen zones of conurbations or large towns	Local survey data in zone surrounding data trom(2) or CORSS etc.	As for (1) but cordon traffic internal trips provide basic pattern	Suitable for study of trip purpose and user calss effects	Provide data for environfment study in chosen zone	As for (1) in chosen zone Could input to e.g. junction design	Road authorites and policy studies by example
(4) Tdealised e.g. CRISTAL RRLTAP (circular)	Strategic And policy Studies	Minimal in some cases a single corridor	5-20	Large towns	If data for(1) available realism improved but trends can be studied using synthetic data	Demard/supply equilibrium models Considerable detail of modes	Mainly by elasticity Time valuation and car availability	Could be used for input to (3)	Corridor speeds and flows .Traffic generation and mode split,user benefits and P.T. .effects	Policy studies whih scope for particular examples
(5) Sector e.g.wmpt Systems Assess COBA	Study of Alternative Projects to Meet a need Shown by (1)-(4)	Homogeneous	0-15	Any	Output from (1)-(4) with access to effects of alternative projects	Mainly mode and route choice formulation with cost and benefit evaluation	Level of aggregation depends on objectjves	Not well Suited to Overall study but local effects could be derived	Performance of chosen routes but network effects largely lacking	Public transport authorities Road buiding authorities
(6) Single Link	Spot checks of effects of particular parameters	Simplified but including all public transport	0-10	Any area which can be regarded as homogeneous usually large urban areas	General Averago values	Single link characteristics only Network and distribution effects not included but a form of capacity restraint possible	User characteristics can be included as an assumption or a parameter	Not appropriate	Useflu quick check on effect of particular parameters but effect of input censtraints on evaluation ennd care	Preliminary studies in connection with types 1-5
(7) Lar d-use Interactoin e.g.	To relate transport needs to planned landuse		10-30	Particularly developing towns and areas with changing employment dictrbution	Existing and planned network Employment locations and residence by class of worker	Type (2),(3) or (4)	User disaggregation usually essential Work trips first priorty but recreation etc. Becoming important	Should be a major component of evaluation	Accessibility is currently widely used but criterla describing the social function of tra sport should be deceleped	Urban Flanning authorities

2.3.2 Theory

2.3.2.1 Statement of problem

The problem of predicting the flows in a transportation system is an application of economic theory: the flows which will result from a particular transportation system (T) and pattern of socio-economic activities (A) can be determined by finding the resulting equilibrium in the transportation market. If:

V = volume of flow

L = level of service experienced by that volume

F=(V, L)=flow pattern

Then, an equilibrium is found by establishing a supply function (S) and a demand function (D), and solving for the equilibrium flows (F_0) consistent with both relations [7][8][32]:

$$\begin{Bmatrix} L = S(V,T) \\ V = D(L,A) \end{Bmatrix} \to\to \{F_0 = (V_0, L_0)\} \quad (2\text{-}1)$$

L = the level of service; T = travel time

While simple in outline the application of the theory becomes complex in practice for several reasons:

1) The consumer considers many service attributes of the transport system when making a choice (e.g. line-haul travel time, transfer time, walk distance, out-

of-pocket cost, privacy, etc.) and thus, L must be a vector with many components.

2) Determining the demand functions (as well as other elements) to use is difficult [32];

3) The equilibrium occurs in a network, where flows from many origins to many different destinations interact, competing for the capacity of the network ; and the form of these interactions is affected by the topology of the network.

Thus, fairly elaborate computational schemes are required to actually determine the equilibrium flows F_0 for a particular (T, A).

In the case of a multimodal network, the symbol V represents an array of volumes vices experienced for all journeys and modes.

Unfortunately, at this state of the science of transportation modelling, while several systems of transportation models exist,there is not even one operational model which solves for these equilibrium flows exactly and directly.

2.3.2.2 Alternative approaches

One particular computational scheme is that used in four-step urban transportation planning studies, In this indirect approach, the equilibrium flows are estimated in a sequence of steps, commonly called trip generation, trip distribution, nodal split, and traffic assignment [9][10].

Correspondingly, the demand function, D, is represented as a sequence of functions; trip generation equations, trip distribution procedures (including the "friction factor" transformation of L), modal split equations, and the minimum-path rules of the traffic assignment procedures.

More recently, alternative approaches have been developed. One approach uses explicit demand models to estimate the equilibrium flows in a direct approach, in a single step instead of the sequence of steps as in the indirect approach, Such explicit demand models combine the functions of generation, distribution, and modal split (and potentially,route choice) into a single process. The first such models were developed for forecasting intercity passenger travel[11][12][13][14][15]. Later work extended these models to urban travel[16][17][18][19].

There are a number of alternative approaches which are or can be taken to predict flows in networks as the equilibrium of supply and demand, Each approach involves specific assumptions, both explicit and implicit, in the choice of demand models[20][21][22] and of the computational procedures for determining equilibrium. Very serious biases may occur in the computed flow patterns, as compared with the "true" equilibrium, if the assumptions and computational approaches are not carefully considered.

In developing simplified models for traffic forecasting, further assumptions and approximations are required. In order to understand the implications of such simplifications, it is important that the assumptions of present techniques be clearly understood.

2.3.2.3 Relationship between conventional and equilibrium models

By introducing a "general share model " it is possible to prove that the conventional four-step model is a special case of an implicit demand model. By doing this, it is also possible to place the two direct and indirect approaches in their proper context. As can be seen in Appendix I. The general share model itself is an explicit demand model, in that the volume V appears only on one side of the equation

$V = \Psi(Y)$, where is a demand function. (2-2)

The notation Y denotes the set of variables which fully characterise the level of service offered by a transportation system, and the pattern of socio-economic activities. For example, in the simple gravity model Y denotes the populations in each zone (P_K), the employment in each zone (E_k), and the travel time matrix(t_{kl}).

In the more general case, of an implicit demand model, volume V appears on both sides of the equation;

$V = \Psi(Y, V)$ (2-3)

Of particular importance is a special case of implicit demand model, the sequential implicit model which can be written as shown in Appendix I.

Because the general share model is an explicit form of demand model, it can be used in a direct approach to computing equilibrium (i.e., a single computational step). Because it can also be expressed in an equivalent sequential implicit form, it also can be used in an indirect approach to computing equilibrium (i. e., a sequence of steps generation, distribution, etc.)

2.3.2.4 Concluding remarks

These theoretical considerations place the two main classes of existing models within a systematic framework, the value of the general share model is recognised as outlined above since it constitutes a general basis for assessing the underlying assumptions of four-step models and for improving present modelling techniques used in urban transportation planning. Furthermore, it is a useful tool when developing simplified models.

2.3.3 Four-step Models

2.3.3.1 Introduction

In the section on theory, the differences between for-step and demand models were briefly outlined. Both model types aim at the same result: the prediction of person or vehicle flows on parts or all of the transportation system. While demand models set out to achieve this result in a single set of mathematical calculations, four-step models employ the stages generation, distribution, modal split and assignment to arrive at the flows.

The models derive their general name from the presence of the above four distinctive steps. The steps form a logical sequence as illustrated in Figure 2-2. It must be emphasised, however, that many different sequences and feedback loops are possible, depending on the level of complexity (or simplification) adopted.

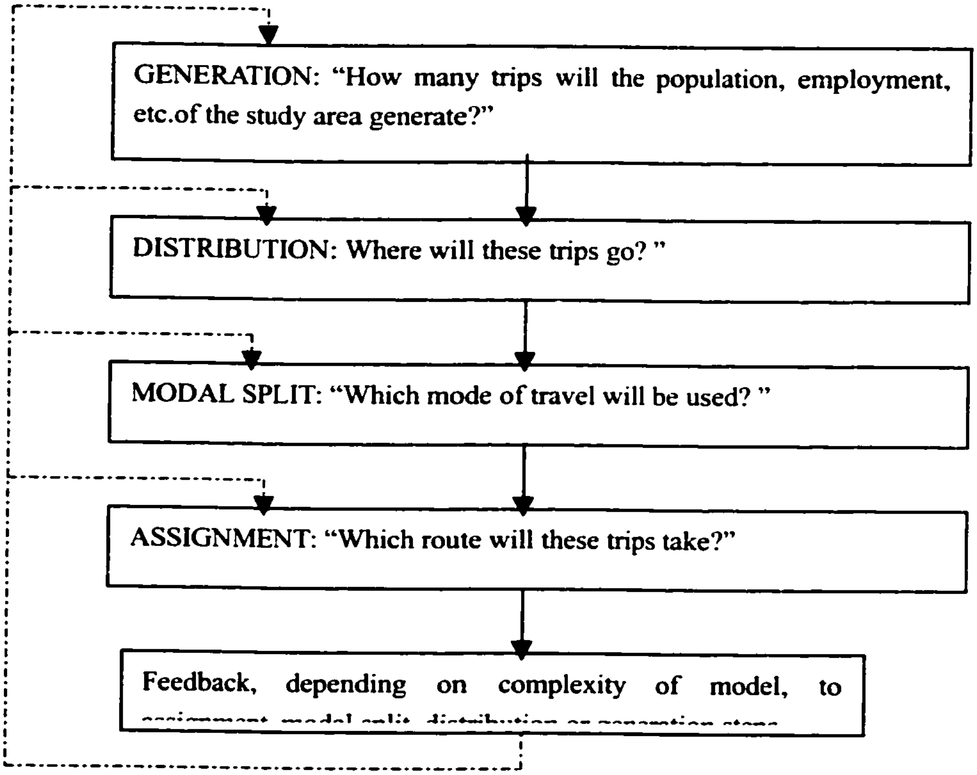

Figure 2-2 Simplified Outline of Four-Step Models

Being largely self-contained, each step lends itself well to computerised analysis. Moreover, within the limitations of existing computer techniques such a segmented analysis procedure can be easily extended to handle large urban areas in considerable detail.

The key question, and one which prompted the establishment of this Group, is whether this increased level of detail, complexity and cost is justified by a corresponding increase in the accuracy and validity of the models relative to what could be achieved by a more simplified approach.

The remainder of this section of the report concentrates on describing important aspects of existing four-step models in order to provide a background against which simplified models can be assessed.

2.3.3.2 Trip generation

The trip generation stage of a conventional four-step model normally consists of a series of mathematical formulae designed to answer the question "given a specified disposition of land uses, how many trips will start from or end in specified areas or zones in the study area?" in this context, a trip may be defined as a one way person (or vehicle) movement from a given origin (e.g. home) to a given destination (e. g. work place).

Hitherto, it has been usual to develop new trip generation formulae for each urban area studied. Much reliable date are required to establish the parameters of the formulae. Most of the data are generally collected from home interviews, that is, interviews conducted in a representative sample of households in the area. The remaining data on travel not generated by households (for example, truck trips), on land uses and on transportation network conditions are collected in supplementary surveys.

The development of a traffic forecasting model based on analysis of an extensive hone interview survey has been the characteristic of classical four-step models, Basically, the "home interview analysis" is used for:

- calculating the number of trips generated in each zone or household
- finding the "constants " for generation of traffic
- finding the present number of trips between zones

- determining the "travel law" or relationship between travel and land use appropriate to the study area.

Likely future changes in the land use plan may modify the travel pattern of the area and account must be taken of this in the travel forecasts.

It is usual to compare the travel found in the surveys and predicted by the traffic forecasting model with the actual traffic crossing several "screen lines " drawn across the city.

The normal method adopted for establishing the parameters necessary to give the " constants " for traffic generation is to carry out some type of regression analysis on the home interview and other survey data. This regression can be carried out in one of three ways at a zonal level, at a household level or by cross classification.

Zonal regression analysis has been used widely especially in early transportation studies. In it, each zone is treated as one unit of analysis. The average number of surveyed trips entering (or leaving) the zone for some particular purpose by a specified mode of travel is taken as one value of the dependent variable, and zonal average values for such items as income, car ownership, number of households, number of persons employed, etc., are taken as one corresponding set of values for the independent variables. The constants of a regression equation relating the dependent and independent variables are then calculated, using sets of survey data from all zones. With this technique, it is necessary to have sufficient survey observations in each zone to provide reliable estimates of the average zonal value of the dependent and independent variables.

Zonal regression suffers from the disadvantages that a linear relationship is usually assumed between the dependent and independent variables, that the independent variables are assumed to be uncorrelated with each other (and therefore additive)and that all variables are assumed to be continuous. Difficulties are also introduced by zonal aggregations which can mask vital effects or introduce bias according to the local conditions [39].

Household regression analysis is similar in operation to zonal regression, except that each household surveyed is one unit of analysis, so that a smaller sample size suffices, Apart from the fact that it has been largely ignored as a trip estimating technique, it suffers from the same disadvantages ages as zonal regression.

Cross classification, though not, strictly speaking, "regression analysis" is, nevertheless, an application of some of the techniques of regression analysis. In it no assumption of a linear dependent/independent variable relationship is made. Cross classification consists of calculating from survey data, the average value of the dependent variable for each of a number of classes, or groups of values of the independent variables. For example, one class might consist of the average number of work trips generated by medium density high income one car owning households. It is thus apparent that a disadvantage of cross classification is the need to ensure that the surveys collect enough data to permit the calculation of meaningful average trip rates for each of the selected classes of households.

Every trip has both a starting point and ending point, and it is thus normally necessary to develop separate sets of generation equations to predict the numbers of trips starting from, and ending in each zone. However, equations such as those outlined above are usually reserved for "internal " trips (trips with both ends within the study area). Less elaborate techniques are used for "external" trips (where one trip end is inside the study area and the other is outside) and "through" trips(both ends outside the study area).

It is necessary to recognise that seemingly precise mathematical formulae which have been developed for trip generation models may still embody a considerable amount of data specific to individual studies.

The presence of many independent variables in conventional trip generation models implies a need for large amounts of survey data for model development. This, in turn, implies costly and time consuming study processes.

2.3.3.3 Trip distribution

Trip distribution models are used to estimate the number of trips made between pairs of zones once the total number of trips starting from and ending in each zone is known, and once some index has been established which expresses the efficiency of the transportation network connecting the zones. Two main groups of models have been developed: Growth Factor and Synthetic.

The basic philosophy underlying growth factor models is that present zone-to-zone movements can be projected into the future solely on the basis of anticipated rates of growth in the zones total generations and attractions. In their simplest form, they use a single factor to scale existing zone-to-zone movements (found by survey) to future movements. More complex versions attempt to incorporate both the absolute and relative growth rates of different zones.

Synthetic models attempt to identify some of the factors which influence zone-to-zone movements[10][24], this is done by analysing existing movements(found by survey)and modifying the parameters of the model until it can predict the present movement pattern to an acceptable degree of accuracy a procedure known as "calibration" These parameters are assumed to remain constant with time, and in this way the model can be used to predict future movements irrespective of the extent of changes in land use.

The general formula adopted for synthetic distribution models (ignoring purpose or mode of travel) is:

$$Tij = p(i)\, a(j)\, f(i,j) \qquad (2\text{-}4)$$

Where

Tij =trips produced in zone I and attracted to zone j

p(i)=factor depending on the production zone I

a(j)=factor depending on the attraction zone j

f(i,j)=factor representing the conductance (e.g. generalised cost) between zones I and j.

2.3.3.4 Modal split

Modal split models attempt to indicate the percentage of trips, which will be made for each purpose by the various modes considered [25]. They fall into two main groups: Pre-distribution and Post-distribution.

Pre-distribution models involve determining the proportions of the productions and attractions in each zone, which can be ascribed to each mode, Separate distribution and assignment models are then used for the modes.

Post-distribution models divide the zone-to-zone person trips, obtained from the generation and distribution models, into person trips by each mode. Separate assignment models are then used for the modes.

The main disadvantage of pre-distribution models is that they cannot easily include any measures of transport system efficiency in their formulae. However, post-distribution models in effect assume that the total number of zone-to-zone person trips is independent of mode, and that the proportion of these trips made by each mode can subsequently be determined from relative travel times or costs on the modes.

In the case of post-distribution models applied to two mode (car and public transport) problems, diversion curves are often constructed which relate proportion of trips made by public transport to the ratio of public transport to private transport travel times. Different curves may be used depending on the parking conditions in the generating and attracting zones, since parking has been found to have considerable influence on modal split.

Other factors which have been taken into account include:

- average income of inhabitants in the zone
- relative travel costs (including car parking chares)

- service ratio, i.e., the ratio between "time spent walking and waiting for public transport" and "time spent walking and parking for private transport."

2.3.3.5 Trip assignment

These models are used to calculate the number of persons using each link of the public or private transport network – figures required both for network evaluation and for design[26]

In its simplest form assignment involves determining the route of the shortest (or lowest cost) path between each pair of zones, adding to the volumes on every link of this route the number of trips given by the distribution model for this zone-to-zone pair, and repeating the process for all other zone-to-zone pairs. This is known as "all-or-nothing "assignment, since all trips between each zone-to-zone pair follow the same route. This technique often leads to unrealistic over and under loading on some links, so the concept of "capacity restraint" is often applied subsequently in an attempt to rationalise the loads.

Capacity restraint generally involves the systematic adjustment of travel times or costs on over-loaded links (and sometimes also on under loaded links)to reflect the levels of service (speeds) which would prevail under these conditions. New shortest paths are obtained as a result of each adjustment, and new "all-or-nothing " assignments carried out, until flows and capacities are adequately balanced throughout the network.

Other forms of capacity restraint exist-for example, adjustments may be made in the generation or modal split models in order to balance car parking demand and supply.

More sophisticated assignment techniques use some form of multiple routing, in which portions of the trips for each zone-to-zone pair are assigned to each of the paths through the network which approximate to the shortest path [27][28].

Another method for determining routes and assigning trips has been developed from probabilistic considerations. these so called stochastic models determine a route based on the trip maker's "opinion" of the route's travel resistance. This "opinion" is generated by Monte Carlo methods. Different routes from a given origin to a given destination can be found. This model lies between the capacity restraint and the multiple routing types.

2.3.3.6 Calculation of peak hour traffic

In developing models to predict the flows on a transportation system, considerable freedom exists for selecting the time period for which predictions are to be made. However, the tendency has been to concentrate on predicting total daily flows. This if based on the assumption that daily travel patterns are more predictable than hourly patterns, so that models developed from 24 hour data will be more reliable than those related to peak (or other) hour conditions. Consequently, although very important for the design of roads and public transport systems relatively little effort has been put into finding formulae for calculating peak hour traffic compared with the effort devoted to models for 24-hour flows.

Peak hour effects have different implications for public transport systems compared with private transport, and different calculation methods are generally used. On the public transport system, peak conditions are often estimated using the work (and perhaps school) trip purpose because these journeys cause the peak loads on public transport. On the road system, the usual method adopted is to take the peak hour flows as being some percentage (say 10 percent, though this may be varied according to location and type of route) of the 24 hour traffic produced by the assignment models. Since there are no exact rules for selecting the percentage figure, there is considerable latitude for error in estimating peak hour flows. A second, and equally error prone stage involves converting the peak hour flows into the directional flows needed for system design.

A refinement of the above method utilises percentage figures which differ for each trip purpose. In this way, a number of "peak hour trip matrices" are obtained from the distribution model, summed and converted into peak hour traffic on the transportation system by means of the assignment model.

The special problems of overloaded networks and resulting speed/flow relations may call for specific peak hour models. Since the peak hour is normally associated with the journey to work, an assignment model which uses only the home to work trip purpose provides a means for directly calculating peak hour flows. Experience in Copenhagen and Stockholm suggests that total traffic in the peak hours is represented by a little less than 50 per cent of the total home to work traffic. However, this percentage is likely to vary considerably with the size of the home to work traffic, However, this percentage is likely to vary considerably with the size of the home to work flow.

2.3.3.7 Appraisal of four-step models

In Section 2.3.2.3 on theory it was noted that the four-step model is a special case of the General Share Models. In conventional use:

1) The trip generation is a function of only activity system variable A (income, car ownership, etc,)and not of any level of service variables L. Thus., it is implicitly assumed that no possible change in travel times, fares or parking charges, etc, will affect the number of trips made per person. This assumption is clearly unrealistic, especially for non-work trips. this partly explains the overall increases in flows observed when new roads, etc. are built – increases which conventional four-step models have failed to predict.

2) There is no direct opportunity for accounting for changes in fares, parking charges, etc. in the distribution model function.

3) It is only at the assignment stage that supply functions are introduced in the four-step models in an attempt to relate supply and demand.

By a process of successive iterations these effects can be allowed for, but this is cumbersome and expensive. The four-step model system is the most widely used transportation systems analysis method. It has been applied in over 200 cities in the United States and in many other cities around the world. The development and acceptance of the approach over the last fifteen years is a major accomplishment; it is one of the first large-scale applications of modern systems analysis techniques to problems of public sector decision-making.

However, because of the limitations mentioned earlier, it is useful to examine the four-step process critically from the perspective of equilibrium theory.

The objective of the equilibrium calculations is to predict the flows $V_{klmp.}$ i.e. the volume of trips going from zone k to zone l by mode m and path p. In the four-step models, equilibrium calculations are structured into a sequence of four steps; this amounts to estimating V_{klmp} in a series of "successive approximations " first V_k, then V_{kl}, then $V_{klm.}$and finally V_{klmp}.

It seems obvious that the following conditions should be met by any set of demand models and equilibrium calculating procedures:

1) The level of service attributes used should be as complete sa necessary to adequately predict travel behaviour. For example., time reliability, number of transfers, privacy, etc. should be included if empirical evidence indicates these important.

2) Level of service should enter into every step, including trip generation (unless an analysis of the data indicates in a specific situation that trip generation is, in fact, independent of level of service for all market segments over the full range of levels of service to be studied).

3) The same attributes of service level should influence each step (unless the date indicates otherwise). For example, public transport fares, car parking charges, waling distances and service frequencies should influence not only modal split but also assignment, generation and distribution.

4) the process should calculate a valid "equilibrium" of supply and demand; the step. For example, the travel times that are used as inputs for modal split,

distribution, and even generation, should be the same as those which are output as results from assignment. If necessary, iteration from assignment back to generation, distribution, etc., Should be done to obtain this equilibrium.

5) The levels of service of every mode should influence demand. Congestion on fares, etc, of each mode should (in general) affect not only its own demand modal split and assignment). That is, there should be provision for explicit cross-elasticities.

6) The several demand functions for each step should be internally consistent.

7) The estimation procedures should be statistically valid and reproducible.

Careful examination of the four-step model indicates it violates each of these limitations of the flow predictions resulting from use of the four-step model. Whilst The model does have important advantages, these do not outweigh its very serious liabilities.

2.3.4 Demand Models

2.3.4.1 Demand/supply equilibrium models

As pointed out in section 2.3.2.2 demand models estimate the equilibrium flows in a direct single step instead of the sequence of steps as in the indirect approach. Hence, the functions of generation, distribution, and modal split (and potentially, route choice) are combined is a single process.

The first such models were developed for forecasting intercity passenger travel[11][12][13][14][15] for the northeast corridor project of the united states department of transportation ,beginning with the Kraft-SARC model, and followed by the work of McLynn, Baumol, Quanft et al[12][13][14][15]. Later work extended these models to urban travel[16][17]. These types of explicit demand models were first used for transportation network analysis in the simulation studies for the Northeast Corridor Project. The Harloff model STADT to predict an optimal arrangement of land use is also a demand /supply equilibrium models[35]. The DODOTRANS system of computer models [29] provides a variety of means of computing equilibrium flows in networks utilising various levels of sevice attributes and with the choice of demand models.

Other examples of equilibrium models in the general class are the models used at the TRRL[18][30][31][88] to study urban traffic restraint (using the RRLTAP suit) and for strategic studies (CRISTAL)[19]. In both the RRLTAP and the CRISTAL approaches the criterion for decision to travel or for route choice is generalized cost of travel. The demand for travel between two points in the system is balanced against this cost using a demand/cost relationship which incorporates an elasticity for the travelers concerned.

The basic iteration loop is shown in Figure 2-3. This concept embodies the essential reaction between supply and demand, permits a high degree of internal consistency in the models since a form of generation and distribution, also assignment and evaluation are on a common framework, and this greatly facilitates the study of the influence of changes in user costs on travel behaviour. There is some difficulty in the choice of appropriate (behavioural) time valuations and user elasticities but the effect of varying these factors can be studied.

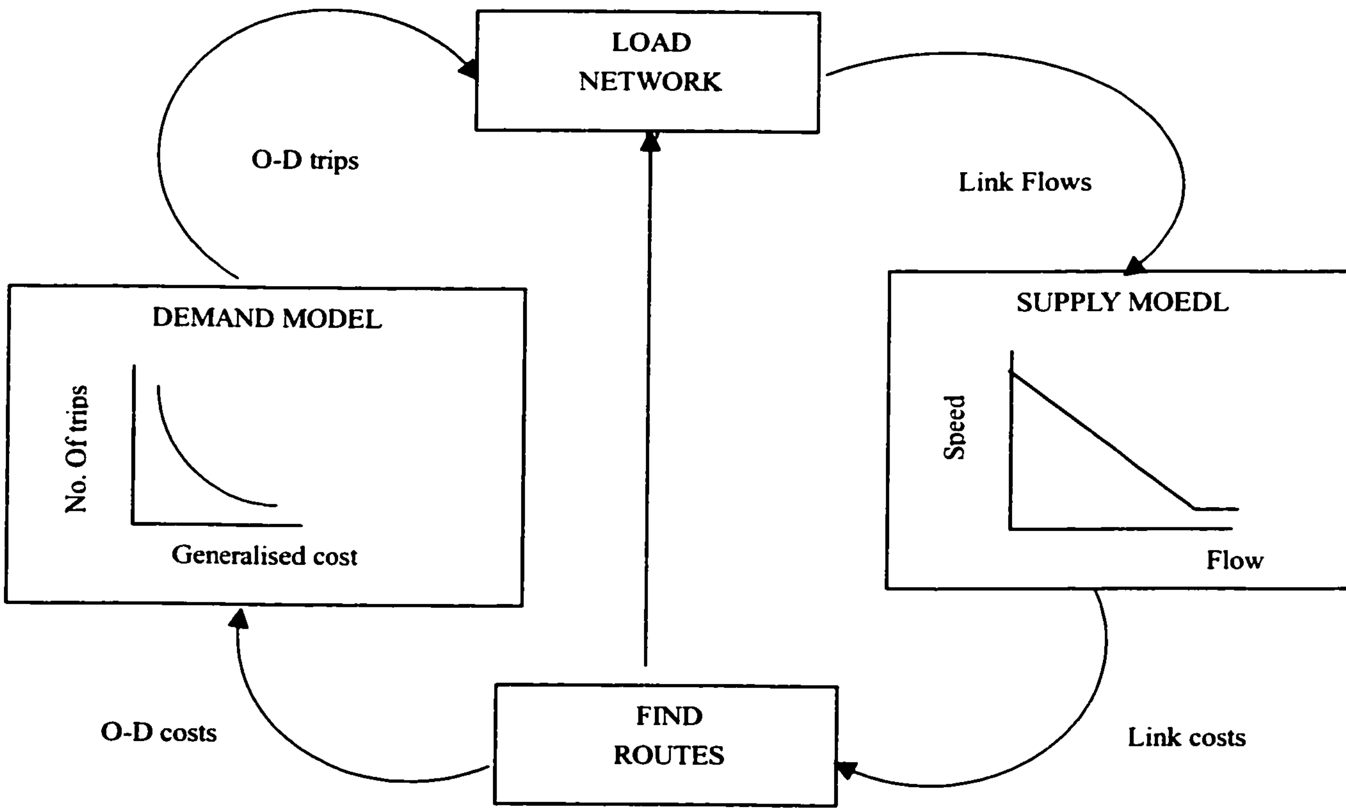

Figure 2-3 Basic Iteration Loop

It has been demonstrated that convergent iteration can be assured and the equilibrium points are stable, unique and well defined. It is also noteworthy that a method of assignment to congested networks has been adopted which does not involve any compromise with the basic benefit evaluation philosophy. CRISTAL[19] follows the principle of an equilibrium model in which an elastic travel demand (adjusted according to car availability ratios), is balanced against a function describing the generalised cost of travel on a network. Five modes (car, bus, rail, taxi an goods) of transport are included and their characteristics are modelled in considerable detail, modal split being dependent upon a chosen cross-elasticity in an inverse power formulation. Peak and off-peak hours are modelled separately and the effective network used has 400 nodes, each of which is regarded as a possible origin of destination point. The simplifying feature which makes this model suitable for strategic studies is the adoption of a circularly symmetrical network with 20 rings and 20 radials; this can be described completely by the data for 19 radial links plus 20 ring links. Each of these links consists of an ordinary road and, when appropriate, a motorway and/or a railway (plus access and walking links). The model has been calibrated against date for London.

Outputs include the ccnsumers surpluses of travelers and for road goods vehicles, the operating costs and revenues of public transport operators, taxation revenues, traffic flows (in aggregate and by link), O-D matrices, journey times etc.

Experience with this model has demonstrated that it is well suited to strategic studies in which a wide variety of alternatives need to be studied without too much detail which are built into the model should again be emphasized in view of the importance of this feature in strategic work.

It should be mentioned that the French ASTARTE model seems to fall into the class of elastic demand/supply equilibrium models.

2.3.4.2 Explicit demand models

Since the four-step model as presently applied has serious limitations, many researchers have focused attention on developing explicit[11][12][13][14][15][16][17] models - i.e., models which can be written down as a single equation. Examples of these are given in Appendix I.

A wide variety of forms of function are possible as well as choices of variables, of specific numerical values for direct and cross0elasticities and of forms of the "generalised cost " function.

Alternative forms of the "generalised cost," can be used, e. g., an exponential transform of this[33], a friction factor transformation of travel time, etc. [11][12][13][14][15].

Recent research has refined the form of models. In early work for the Northeast Corridor project in the United States, the Kraft-SARC model was developed for intercity passenger traffic. This model, as illustrated in Appendix I features: (1) incorporation of several activity system variables; (2) incorporation of several level of service variables (time and cost); and (3) incorporation of "cross-elasticity "effects, i.e., the demand for travel by mode m is affected not only by its own level of service but also the service offered by competing modes n. Other models developed later - e.g., the McLynn and Baumol, Quandt - have similar properties, although the cross-elasticity effects were not expressed so clearly in the model structure [14].

2.3.5 Urban Dynamic Eevelopment Models

The field of strategic traffic models involves close contact with land use planning and dynamic models of the resulting interaction are currently being developed.

The main goal of an urban dynamic development model is to collect and assemble all aspects of town development, to evaluate their interrelationships in an optimizing process and to quantify their implications. The data requirements imply that they cannot be regarded as simplified models.

The Polis model[34] is still being developed. It will eventually describe urban development with regard to traffic and land use; furthermore it will consider economic, social, cultural and political implications as well as environmental aspects. The model consists of several submodels with sequential runs as well as feed-back-loops. The model becomes dynamic by introducing time intervals, which may be varied by length and number. The traffic system is taken as the independent variable while land use is considered to be the dependent variable. The model structure is contrary to the normal transportation planning algorithm. The supply by a traffic system is considered to be the main impulse to urban development. The simulation makes use of traffic generation-, attracton-, distribution-, modal-split and assignment-models.

The Stadt-model[35] attaches the various types of land use to areas in a town and to the regions attached to it by a relation between land use and essential supply services. The goal-function in the standards of linear programming tries to minimize overall costs taking due account of traffic loading and any constraints. The essential supply of the types of land use must be these systems are the constraints for the allocation of land-use units. The computed model output is the amount of traffic by mode on the system in addition to data on land-use in each cell in the planning area. The system of numerous constraint-equations is able to formulate the conditions of the real world, of social standards and goals and of a development without contradiction.

Another group of models is based on the Lowry-model. One of these is the Swiss ORL-MOD 1[36]. The elements of ORL-MOD 1 are nearly the same as in the Lowry-model. Around this, distributing the activities of land-use, several sectoral single-purpose models have been grouped to assemble data, to compile them and to prepare the outputs.

The Besi-model[38] is in its model structure very similar to the Forrester model. It consists of several sub-models:

-managing the goal system of town development,

-handling data for an information system.

-operating for a strategic planning phase,

-operating for a tactical decision phase,

-describing the operating system.

The Besi-model has been conceived as a community management and information system setting out the structural changes in a large town according to their economic impacts. The whole set of submodels is not yet developed.

In general no urban dynamic development model may be regarded as an ideal one. Methods of systems analysis seem to be a promising way in developing better models, which make it possible to take into consideration a great variety of alternative concepts at reasonable costs in a reasonable time.

2.3.6 Appraisal of Implications for Simplified Models

The above discussion has a number of practical implications for the development of simplified urban travel forecasting models.

1) It can be proved that any explicit demand model is a special case of the general share model(GSM): that any sequential implicit demand model(which meets certain "internal consistency" conditions) is also a special case of the GSM; and that as a consequence, every demand model can be used in either its explicit or its sequential implicit forms(7). Therefore, the developer of simplified models is free to choose whether he wants to use a single-step (i.e., direct) approach to computing equilibrium with an explicit demand model; or a multi-step (i.e., indirect) approach with a sequential implicit demand model.

2) In particular, the conventional four-step approach is only one of many possible approaches. Because the four-step model has serious limitations, other approaches should be explored actively.

3) It is practical to calibrate various forms of explicit demand models. Empirical results already exist[11]-[17].

4) Particular attention should be given to the question of which and how many level of service and activity system variables should be included in any model.(The limitations in the generation, distribution, and assignment phases of the four-step model probably introduce significant biases).

5) Thus it has been demonstrated that there is a systematic theoretical link between explicit demand models and more conventional transportation models. This has indicated the importance of the explicit demand models in avoiding large systematic errors and in opening the way for reducing the amount of data which has to be handled to describe real situations effectively.

6) Despite the foregoing conclusions drawn from work on the theory of transport models, the majority of simplified models at present in use still follow the conventional four-step approach. Internal consistency is a vital feature of models which are to be used for the strategic phase of urban planning in which possible generation or suppression of traffic will play an important part and this is mot usually present in four-step models. Equilibrium models are especially suitable for use in simplified traffic models since it is possible to demonstrate the accuracy of solutions derived. This feature is largely lacking in the overall results obtained by four-step processes. The attraction of the four-step process is that items like traffic generation can be separated out and related to physical proposals but care must be exercised to avoid the danger of thereby introducing an unrealistic bias. It should be pointed out however that equilibrium models can also provide this facility.

7) The CRISTAL model is an example of simplification in the network in order to avoid compromise on the equilibrium formulation in the model. This suggests that simpler models do not necessarily conflict with the idea of correctly representing demand/supply interaction.

8) There is no doubt that a lot can still be done using versions of the conventional four-step model but work on the theory and practice of a new generating of explicit demand models and methods of improving data inputs promises to offer important improvements in the effectiveness of simple models.

Chapter 3

MODELLING AND ANALYTICAL METHODS FOR STRATEGIC MODELS

CHAPTER 3

MODELLING AND ANALYTICAL METHODS FOR STRATEGIC MODELS

This chapter describes the work for modelling and analytical methods for strategic models. First section contains an overview and the latter sections study the issues that arise in connection with particular aspects of the transport planning process in developing areas with high-speed economic development.

3.1 Model Simplification

3.1.1 Introduction

The simplifications to conventional models have been introduced in the data collection stages, in the way in which the various travel purposes or modes are treated, in the land use groupings, in the degree of accuracy acceptable for travel predictions, in the details of the mathematical formulae, in the study procedure itself, and also can be through new methods of handling networks, new forms of the mathematical formulae built into models, and developments in computer procedures[24].

3.1.2 Simplification of Conventional Models

Five main types of simplification within the methodology of conventional (four-step) models have been studied.

In the first method, simplification is achieved through the restriction of travel purpose of the models to two purposes (home/work and home/other). In the case of home/work travel, calculations are made with a gravity model using numbers of employed residents and employment per zone. Regression analysis based on car ownership level is used for estimating home/other travel. Researches indicate that the models reproduce survey data to within 15 percent.

In the second method, simplification is achieved by adopting a regional rather than detailed level of analysis. This has permitted simplification in the data collection stages, with travel models being developed on the basis of a 1 percent home interview sample size. Categories analysis trip generation model permitted the reduction in sample size. Modal split was incorporated in the generation model. The validity of the model process was checked by comparing synthesised and observed flows across selected cordons, a calibration accuracy of within 9 percent was indicated.

The third method of simplification concentrates on reducing computer analysis time by adopting an "in-core " set of programmes, a " once-through" thee building and loading algorithm and a doubly constrained gravity model for rapid convergence. This has been used in the IMPACT model which can handle up to two modes, 150 zones, 500 nodes and 2,000 links. A generalised cost function is used to reflect travel impedance with a simplified method of estimating intrazonal costs. Applications of the model have included examinations of large investment alternatives. It has been found possible to aggregate zones for this purpose of analysis, with meaningful results being obtained with aggregation from 362 to 32 Zones.

Another simplification consists of a modification to the gravity model formula so that a future trip matrix can be predicted from an existing matrix. This modification uses only the future and existing zonal generation and attraction values (based on expected land use alterations) and the existing trip matrix.

The modification equation could be written like below:

$$Tij = Pi * \frac{Aj * FF'*(GC'^{**\alpha} * e^{(\beta * GC')})}{\sum Aj * FF'*(GC'^{**\alpha} * e^{(\beta * GC')})} \qquad (3\text{-}1)$$

$$Pi = POPi * Ri \qquad (3\text{-}2)$$

OR

$$\begin{aligned} Pi &= aPOPi + b \\ Ln(Pi) &= aLn(POPi) + b \\ Pi &= [(a / POPi) + b]^{-1} \\ Pi &= aLn(POPi) + b \\ Ln(Pi) &= aPOPi + b \end{aligned} \qquad (3\text{-}3)$$

$$Aj = EMPj * Rj \qquad (3\text{-}4)$$

OR

$$\begin{aligned} Aj &= aEMPj + b \\ Ln(Aj) &= aLn(EMPj) + b \\ Aj &= [(a / EMPj) + b]^{-1} \\ Aj &= aLn(EMPj) + b \\ Ln(Aj) &= aEMPj + b \end{aligned} \qquad (3\text{-}5)$$

where: T_{ij} = *future trip for any i-j pair*

P_i = *productions in zone i, only be classified as Home/Work and Home/Other two purposes*

POPi = future land use alteration, as population in zone i

Ri = future average trip rate for zone i, Ri is different for different kind of land use

a,b = statistical parameters for future trip production forecasting

Aj = attractions in zone j, only be classified as Home/Work and Home/Other two purposes

EMPj = future land use alteration, as employment in zone j

Rj = future average trip rate for zone j, Rj is different for different kind of land use

a,b = statistical parameters for future trip attraction forecasting

FF' = friction function (minutes) related to distance obtained from the existing zonal values

GC' = generalised travel cost utility (minutes - including time and money cost) obtained from the existing zonal values

GC' (mins) = travel time (mins) + travel cost (mins)

*travel cost (mins) = money (cents) * Value of time * scaling factor*

a,b = calibration parameter obtained from the existing trip matrix

This simplified model is very useful during strategic transport planning process in developing areas. It is because, using this model, the main corridors of the development for the railway network or the road network could be easily figured out, which are most important aspects should be considered during the strategic stage. However, while conducting the detailed level transport planning, this model is not very much adequate due to the accuracy of the data.

Finally, simplification is that the models developed in one city have been applied directly in another city without having to carry out large O/D surveys. A forecast is made for the present situation which is checked against measured flows and calibrated until predicted and measured flows agree to a satisfactory degree.

3.1.3 Simplification of Modelling Procedure

Three types of simplified model procedure are studied.

The first makes use of information collected in a number of "conventional " travel studies. Average generation factors are calculated and used to predict the private travel generated by suburban residential areas. Various formulae are presented. These can be used to provide a rapid estimated of traffic conditions with more complicated (conventional) models used to determine the final network loads.

The second type involves restricting the process to one category of trip and combining the trip generation and modal split stages. In addition, it involves dividing the forecasting stage into two steps. The first step uses growth factor techniques to predict the growth in travel arising as a result of increased affluence, etc., among the existing inhabitants of the city. The second step estimates the growth in travel due solely to new population, new developments, etc. A number of simplifying methods are suggested for completing this second step. All dispense with home interview surveys and instead rely on traffic counts, on screenlines or on average trip generation values from other surveys.

The third type dispenses with comprehensive O/D surveys and instead of making use of the averages of travel data collected by previous studies. It divides the study area into a small number of zones for each of three classifications. The criteria for zone boundaries are different for each classification, so zones may coincide or overlap. For each zone, normal information (such as population, employment and land use) is collected, along with much information of a qualitative nature. These along with the average travel data and models from other studies, produce synthetic travel patterns which can be checked for validity by comparison with observed traffic flows at selected points on the network. Computer coding and analysis is not required, since a simple zone and network system and assignment procedure are used. There is close co-operation between the land-use planners and transportation planners at all stages of the analysis and evaluation. Because of the reduced amount of data collection and analysis, more effort can be devoted to examining and evaluating different land use network alternatives.

3.1.4 Simplification of External Aspects of Models

The main features of this type of simplification lie in having models with clear logic so that non-technical decision makers can understand the relationship between input and output. They can then appreciate the close link between land use and transport infrastructure needs, and understand better the problems of the city center where most density and network conflicts arise[6]. The models require few input data, produce clear output information, give a rapid turnaround and can be easily and simply explained. The models consist of a conventional generation-distribution sequence, with complementary stages for modal split, assignment to predetermined routes and analysis of city center parking. The models are based on the computer packages FABER and PARK[49]. Smaller deviations (10 percent to 15 percent) are obtained when the model gives different weightings to trips depending on whether they originate in the city center or suburbs.

3.1.5 New Modelling Techniques

3.1.5.1 Network handling

Three methods of simplifying models through improved network handling are studied .

In the first method, a model has been studied which generated networks for investigation.

The assumption of a circular symmetrical network is basically another useful method. As a result, computer analysis time is greatly reduced, and many strategic alternatives can be examined .

Another simplified model developed[89] involved the representation of the study area by its "average main road ". The model has been used to determine optimum bus size, and calculate community savings arising from a transfer from cars to buses. In the model, the average speed on the network is calculated from observed speeds and speed/flow relationships at various points. Speeds are modified to allow for car parking and bus walk/wait times. Travel time is then converted to journey costs per kilometer of network per hour ,and the procedure repeated for various car restraint and public transport size options .

3.1.5.2 Equilibrium methods

New mathematical techniques are being investigated which could aid the development of simplified models. Some of these techniques are based on the concept of the General Share Model (GSM). Starting with a mathematical expression for the total amount of travel in the study area, the GSM successively splits this total until it has identified the fraction of this total which is made on a particular path by a particular mode between a particular pair of zones (see also Appendix I.)

A special case of the GSM is the Explicit Demand Model (explicit, in that volume appears only on one side of the equation). This provides a "single step "method for computing equilibrium in the transportation network. In the more general case, the GSM can be written in an implicit form (implicit, in that volume appears on both sides of the equation). A special case of the implicit form is the sequential implicit model, in which equilibrium is calculated in a series of steps analagous to generation /distribution /modal split/ assignment.

3.1.5.3 Calibration methods

Previously developed demand models have been aggregate deterministic models in that they describe the behavior of groups of people, indicating the number of people who travel under specified level of service conditions. Recent work on disaggregate stochastic models deals with the travel behavior of individuals and give explicitly the probability of the individual's making a specific choice[4][5][20][21][22][75][76][77]. These disaggregate models allow much greater efficiency in the use of small samples of the order of 1,000 observations for calibration. Once developed, disaggregate models can be transformed into equivalent aggregate once.

3.2 Changes in Land Use

The main, and often the only, aim of early urban transport planning studies was to satisfy traffic demand estimated on the basis of the underlying urban development assumptions and objectives, Thus, the traffic models used were simply aiming at estimating, with the highest degree of accuracy possible, the amount of traffic in the target year.

Almost all traffic models presently available were developed along the same line. However, the relationship between transport and urban development is not one-way; transport conditions have a considerable effect on the development of an urban area. Results of traffic studies are therefore being used more and more to modify and adjust land use variables instead of considering them as being intangible basic assumptions likely to prove unrealistic. It is thus possible to obtain dynamic interaction models of transport and urban planning which reflect the interdependency of these two sectors.

In view of the modification of land use variables the two following aspects related to the application of models are successively considered:

i) the relationship between transport planning and land use,

ii) the implications for traffic models and possibilities for simplification.

3.2.1 The Relationship between Transport Planning and Land Use

Application of traffic models to land use problems may be put under three headings:

- long term static coherence of transport network and urban development;
- dynamic interaction of accessibility and urban development;
- control of land use by regulation and pricing

3.2.1.1 Long term coherence of transport network and town planning objectives

This phase of research to achieve long term coherence is important in that it is often the first and sometimes the only aspect to be approached in the practical planning process. The introduction of land use characteristics is necessary because they determine the amount of traffic generated and consequently the transport network to be provided. However, the technical and economic difficulties they raise concerning transport facilities may very often be considerable and the initial urban planning objectives may therefore have to be re-examined. Experience has shown that the general plan and objectives finally adopted for urban development almost always stray away from the initial concept and this result of applying traffic models is just as important as the development of the transport system.

Studies have brought out two particularly critical problems that could justify a revision of urban development assumptions; the problem of increasing density in the center and that of establishing a public transport system with its own right of way.

3.2.1.2 The problem of increasing density in the center

Elected representatives and town planners usually favor increasing the density of employment (especially tertiarv) in the center and also, in some cases, that of the population.

The function of the traffic model is to show the cost (in terms of transport infrastructure) of pursuing such a policy.

To contribute to this, models should faithfully represent the traffic variations as a result of varying land uses in the center .It will not be sufficient, in particular, to know the overall number, per zone, of tertiary sector occupations; indeed the traffic generating pull of such occupations varies considerably, some of them being in offices closed the public and other commercial occupations attract a great deal of traffic. In one center, 62 percent of the trips were attracted by 34 percent of the occupations .

Generally speaking, application of the model leads up to the following (policy) options:

- either reduce the growth of central tertiary occupations;
- or step up provision of new roadways and parking places;
- or, in fairly important towns ,create "segregated " public transport systems.

Whatever the choice or combination of choices, it will have repercussions on land use which must be clearly expressed.

3.2.1.3 Establishment of a public transport system with its own right of way

The success of such a project closely depends on the policy in regard to land occupation near the stations. Patronage of public transport does indeed depend to a very great extent on the terminal time and walking distances that have to be covered on foot.

It will be generally necessary to:

- concentrate most of the new central area tertiary occupations within 300m of the central area stops.

- Concentrate within 500m of peripheral stops the largest possible proportion of new collective housing.

Such projects should therefore be assessed by means of a public transport patronage model sensitive to terminal time and walking distance.

3.2.1.4 Dynamic interaction of accessibility and urban development

A new public transport infrastructure (own right–of–way or metro) can very considerably alter the accessibility map of a built-up area and it will also directly and powerfully affect spontaneous urban development.

Long term town planning cannot therefore merely seek to maintain static coherence between development and public transport; it will also have to check, at each stage of transport development, that the stimulus to urban development is in keeping with the final objective; it will thus be possible to review policy and control of land use [41].

The concept of these models is based on the measurement of overall satisfaction of residents, employed or not, in terms of freedom of choice. Accessibility which combines both the various choices offered by the city and the possibility of access reflects better than other variables the overall satisfaction obtained.

The aim is mot necessarily to create an exact model of urban development. It seems, however, that the use of an accessibility model improves the validity of the basic land use assumptions and that the model could become a basic tool for urban planners.

3.2.1.5 Control of land use by regulation and pricing

Traffic models can have several applications in this field:

- regulation of the number of parking places in new buildings: construction of parking places to be encouraged or locally limited according to circumstances;
- a differential tax according to central area land use .

Transport models may thus be used for real estate market guidance in step with "real costs".

3.2.2 The Implications for Traffic Models and Possibilities for Simplification

The first objective is to obtain a rough estimate of generated traffic on the basis of given land use assumptions.

For optimum refinement, a considerable number of variables must be taken into account, the number soon becoming too large for practical purposes. In particular, the following factors should be taken into account for each zone:

- residents ,by household size income level and degree of motorisation;
- employed residents ,by category of occupation (this will easily amount to 10 to 20 categories ,i.e., shop , office , etc.);
- point generators: large stores ,hospitals ,schools.

The need for simplification is evident. Simplified strategic generation models use the following variables (applied to 30 to 50 zones);

- total number of residents
- total number of employed residents
- total number of occupations
- proportion of tertiary occupations

These models have been tested by comparison with the data gained from household survey interviews. The weighted error affecting traffic generation is of the order of 10 to 20 percent (variable according to motivations) assuming that the overall number of trips in the urban area is accurately known.

Obviously, part of the error is the result of simplification. For example, the models do not take into account the relative distribution of tertiary occupations, i. e., the breakdown between really attractive employment (stores, offices open to the public).

It would appear that the only solution would be to differentiate tertiary occupations into more homogeneous categories, this may well lead to resorting to more complex approaches, which would defeat the very object of simplification.

However, accuracy can be improved without adding to the complexity of the land use parameters. It has been found that the relative distribution of tertiary occupations is fairly constant in the centres, hence the concept of treating land use data differently according to the type of zone has led to the development of a set of correction coefficients to be traffic generation and attraction according to the type of zone and trip motivation.

It has been shown that this approach results in a marked gain in accuracy, especially as regards trips related to the central zones where transport problems are the most severe.

It will be noted that this increase in accuracy is obtained without adding to the weight of required date, the only supplementary information being the type of zone.

The second objective worthy of mentioning relates to the dynamic interaction of accessibility and urban planning. It assumes that for each zone the accessibility can be calculated.

In this connection, the problem concerns not so much the land use data but, rather, the measurement of trip times. Trip times, especially when the transport networks are congested, can be assessed only after implementation of traffic distribution models with capacity restraint ,which can not be considered as simplified models .

A degree of simplification can be attempted by substituting, for the trip times, point, to point distances, in the accessibility relation. In that case, simplified models of the type described may serve the desired purpose though at the cost of accuracy (especially in the presence of traffic congestion).

3.3 Public Transport Aspects

Many problems in the field of pubic transport may be tackled with the help of simplified models (optimum positioning of bus stops, organization of connections, priority at crossings, etc.)

If it is confined to long term planning, the main contribution to be expected from a model of public transport demand will be evidence that any improvement of the situation will not automatically follow a stroke of a planner's pen and that it requires a very considerable effort of improvement in supply.

Such models should therefore essentially establish and quantify the link between the supply of public transport and the demand for it .Here again, it is essential that such models should be as logically simple, convincing and instructive as possible in their choice of explanatory variables. This is essential to convince policy makers and the administration of the project and to dispel any impression that their decisions will be arbitrarily dictated by an incomprehensible model.

At first sight, the demand for public transport seems to be governed by a large number of factors including:

- choice (possibility or not of using a car)

- trip purpose (in town ,suburb to centre ,suburb to suburb)
- frequency (waiting time)
- operating speed
- comfort
- number of changes
- initial and terminal distances on foot (concentration of dwelings and employment around stops)
- reliability of time-table (respect of design frequency)
- fares
- own right of way or shared use of roadway
- parking facility in town (charges , prohibition and repression of parking, control policy, time required to find a place)
- congestion level of roadway.

These variables are not all independent of each other.

It is, of course, possible to design a model which will take every one of them. Into account, but it would be too unwieldy for strategic planning.

Another approach must therefore be used by arranging the factors mentioned in order of priority and by including only those strictly required to obtain the required degree of precision (it is assumed that the factors left out are partly reflected in those that have been included).

Particular examples of simplified models are considered below.

3.3.1 Generation Models by Mode of Transport

On the basis of total traffic generated, a separation between the different modes is made by means of an overall evaluation of the service provided to each zone by each mode.

These models do not indicate the relationship between the transport network (quality of service of each public transport line) and public transport patronage and this disadvantage cannot be avoided. In fact the quality of service can only be taken into account once traffic has been distributed to the different modes of transport.

3.3.2 Models Based on Tables of Modal Split

These models are based on a set of tables giving the level of public transport use according to zone of origin and destination.

The tables will generally have to be split up according to trip purpose and whether or not public transport has its own right-of-way. Car ownership which has a very important influence on individual choice does not need to appear as such if it is assumed to be more or less equal throughout the center, and throughout each of the first and second zone "rings". It will be sufficient to take it generally into account in drawing up the table.

Table 3-1 an example of a built-up area of which the population is 170,000.

Table 3-1 Level of Public Transport Patronage
(percentage of trips by vehicle)

Type of trip	Home-work	Home-other purposes	Secondary
In town centre	5	5	5
Town centre-first ring	13	12	6
Town centre-second ring	20	14	5
Peripheric	15	13	5

Although such a method is very workable, it is rather unrefined and uses levels that are somewhat arbitrary .It can be used for an initial approach, but it cannot be said that it satisfactorily quantifies the link between the quality of service and the load factor or patronage of public transport.

This drawback however may be partly overcome by refining the tables, i.e. by sub-dividing the area considered and identifying the zones affected by public transport (in general a corridor of 500m width either side of the public transport line). This will take into account public transport right-of-way effects and interchange penalties.

The following Table 3-2 is another sample table. It presents public transport patronage for the zones affected along a route as a function of the quality of the mode (subway, bus, direct lines or with interchange) and the type of zone (e.g. parking possibilities).

Table 3-2 Patronage of public transport for the zones of influence along a line
(percentage of trips by vehicle)

	Town centre to town centre		Outskirts to centre		Centre to outskirts		Outskirts to outskirts	
	Work	Other	Work	Other	Work	Other	Work	Other
Subway direct	85	70	80	50	70	40	50	35
Subway + subway	80	60	70	45	65	35	45	30
Subway +bus	75	50	60	35	55	30	40	25
Direct bus and bus +bus	70	35	40	25	35	25	30	15

3.3.3 Models Comparing Level of Service of Different Modes

However refined they may be, the tables are still to some extent arbitrary and empirical and only imperfectly reflect many of the above-mentioned factors.

If a better assessment is required of the impact of different measures connected with public transport-and more particularly of the patronage to be expected on a new line or service having its own right-of-way –it will be necessary to go back one step in the priorities and compare the level of service offered to users by the different modes of transport (private car, public transport ,two wheeled vehicles).

Systematic research was undertaken in France into the form of such a model and on the minimum number of variables to be taken into account . Basic data were obtained from house-hold interviews. This research has given the following results:

(1) Zoning

A detailed link by link analysis calls first of all for zoning sufficiently refined to show whether dwellings and work destinations are accessible from the public transport considered (i.e. less than 500 m from a stop).

(2) User categories

A distinction has to be made between two categories of users;

- those who have a car and usually choose between their car and public transport
- those who do not have a car and who have to choose between public transport and possibly a two wheeled vehicle.

(3) Choice between private car and public transport

Trip purposes were split up under "home-compulsory" (work, school, daily shopping),"home-optional" and "secondary".

The explanatory factor to be determined was the relationship between travel time by private car and by public transport. This factor gave satisfactory results. However, it was necessary to introduce the following corrections with regard to travel time:

- private car: penalties reflecting parking difficulties
- public transport
  - a coefficient of attraction in the case of own right-of-way

- a coefficient for interchange penalties

In order to simplify and avoid a generalised cost model,it is possible :

- private car

  to standardise the time penalties due to parking problems by only differentiating between the type of zone (CBD, centre, first ring ,second ring)

- public transport

  to indicate that the penalties mainly concern short trips (waiting and walking times representing a considerable porton . The penalty coefficient is :

$$1+\frac{15}{d} \qquad \text{where d is the distance in km.} \qquad (3\text{-}1)$$

(4) Choice between private car and two wheeled vehicles

It is sufficient to correct the rime per rwo wheeled vehicle by a coefficient representing the density of public transport lines (expressed by the logarithm of urban density).

3.3.4 Explicit Demand Models

The traveler's decision process in public transport mode choice is complex. Some work [79][80] utilizes explicit demand models estimated statistically from available data [17].

Essentially, these methods use the demand model in a "pivot point " approach based upon existing conditions. The elasticity E of public transport volume with respect to a change in some level of service attribute, such as schedule frequency, can be devised from the explicit demand model. Then, given the existing volume over a route V and existing frequency F, and the new frequency F, the new volume can be computed approximately as:

$$Vi - Vo = E \bullet \frac{(Fi - Fo)}{Fo} \bullet Vo \qquad (3\text{-}2)$$

This method has been applied by hand for very quick and inexpensive appraisal of changes in public transport service.

3.3.5 Concluding Remarks

The main conclusions are as follows:

1) A simple table of modal split will give a rough estimate of public transport patronage for strategic planning purposes. Such a table is not however very sensitive, except by means of arbitrary corrections to the main variables (improvement in frequency, establishment of own right-of-way, urban density around stops).

2) More complex models based on comparison of times and level of service of different modes give satisfactory results with curves that are independent of the built-up area considered - and which are therefore universal.

3) It is however, possible to simplify those modal split models which involve the comparisons of generalized costs.

There are three possibilities:

- the generalized trip costs could be approximately evaluated by using the distance as the crow flies. This means that one can avoid breaking down these trips, connection by connection, into their various components (walk, waiting for bus, time spent looking for a parking space, etc.)

- detailed analysis of car journey times (which entails the use of elaborate models to simulate congestion) can be avoided if one uses "a priori " the average speed on the network.

  To simplify even more, direct comparison between travel condition by car or by public transport can be avoided; one only needs a variable for the quality of service in public transport (e.g. the number of changes).

  The ultimate stage in simplification is the use of models based on tables of modal split.

- one could also consider combining all trip purposes , or all types of users (whether car owners or not).

  However, even for strategic planning purposes, such simplification may have drawbacks. If one combines all trip purposes it is then impossible to determine the effects of a parking policy on public transport users; these effects differ considerably, depending on whether the trip is connected with work or for another reason.

4) explicit demand models can be used to estimate modal behavior, using a pivot

point approach.

In conclusion it seems almost impossible to develop a modal split model which is both simplified and adapted to all kinds of strategic planning objectives. However, at least unnecessary complications of modal split models should be avoided.

3.4 Modelling New Modes

The problem that arises in using four-step models to assess new modes is that although the models are calibrated to determine the values of the zonal and deterrence parameters, these are not strictly parameters at all, but undetermined multipliers, i.e., they are variables of the system and any change in system characteristics will cause the undetermined multipliers to change also. This is not considered to be too serious a problem when it is assumed that the changes that are made to the transport systems will have only marginal effects on general expenditure patterns and changes in the undetermined multipliers will be minimal. The consistency that has been obtained in calibrated values of the deterrence parameter in different studies is seen as some justification for this assumption.

3.4.1 Definition of New Mode

Care must be taken about the definition of a mode[52]. Two questions arise, firstly the decision of whether or not the "new mode" in question is an addition to the number of modes in the system or is simply the upgrading of an existing mode; secondly , if it is decided that the "new mode " does indeed alter the number of modes in the system, can this still be seen as a marginal change that will not affect the values of the undetermined multipliers? The answers to these questions are at present unclear. A current development is to introduce a distribution of zone-to-zone generalized costs for journeys by each of the modes. Travelers are then assigned to the least cost mode. It is hoped that this procedure will remove the problems outlined above.

3.4.2 Abstract Mode

A major problem in assessing new modes of transportation is that of specifying the disutility of travel by the various modes. Early work concentrated on the abstract mode approach. A mode is seen merely as a means of achieving a transformation through time and space, the traveler being required to make certain inputs into the process (money, time, etc.). Alternative modes are seen as alternative potential transformations and the task for the traveler is to choose that mode which yields the minimum level of disutility. A mode is thus seen as one combination of a set of common characteristics that relate to all modes, and it is in this sense that the modes are considered abstract. With this approach the introduction of a new mode is no problem, all that happens is that an additional potential transformation is introduced. The traveler processes the new information in the same way that he did with the original set.

3.4.3 Practical Application

Although this framework allows the problem of the introduction of a new mode to be handled at a conceptual level, there are problems with the practical application of such a model. The difficulties relate to the empirical specification of the disutility functional; in general, the modal characteristics that are easily quantifiable are money costs, travel times, and walking and waiting times. These characteristics have proved insufficient in explaining modal choice satisfactorily, and additional explanatory variables have had to be introduced that are specific to individual modes. These variables allow for the effects of the non-measurable characteristics and thus destroy the "abstract " nature of the approach. This creates great problems when a new mode is introduced into the system; it is necessary to know the value of the mode-specific parameter before the patronage that the mode will attract can be assessed. With a new mode, all that can be done, given the current state-of-the-art, is to guess the values of such parameters from intuitive reasoning such as: new mode X appears to provide a service that is inferior to that of a car but superior to that of existing buses ; hence, the mode-specific parameter for X will lie between the values for car and bus. Such a procedure is imperfect, but necessary, if estimates of the patronage of new modes are to be made. Work is needed in this area of specification of disutility functions to allow a more satisfactory method of estimating usage for new modes.

3.4.4 Generated Traffic

Trip generation is another area in which the usual assessment procedures are less than satisfactory for new modes of transport. These procedures relate zonal trip productions and attractions to the gross demographic and socio-economic characteristics of the relevant zones. Hence, the level of trip making is invariant to the transport networks. This is one of the more worrying aspects of the normal four-step process; the total level of trip making as well as the distribution of trips and the mode of transport chosen, would be expected to depend upon the quality of the transport networks provided. The equilibrium models used at TRRL overcome this question. Also most transportation studies do not concern themselves with walk trips or bicycle trips, but concentrate on vehicular transport. Thus, there is no mechanism to allow for diversion of these trips to vehicles. Some novel modes of transport are specifically geared to act as distribution systems, e.g., moving pavements, automatic tracked vehicle systems, etc., and are likely to be competitors of the non-mechanised modes. Failure to consider the effects of such systems on non-mechanised modes could lead to serious underestimates of potential patronage, but at present there is a shortage of adequate data for this purpose.

3.4.5 Social Aspects

Another aspect of the demand for new transportation systems is the service that could be provided for disadvantaged sections of the population who may not have a car available and who may suffer from limitations in their ability to use some forms of public transport (e.g. the old, the young, physically handicapped, etc.). such social questions may affect patronage to some extent but would also have an important bearing on the relative evaluation of possible new systems. In studies where social implications are important it may well be necessary to stratify the traveling population in considerable detail in order to identify the sections deriving benefit. This reduces the possibility of simplification.

3.4.6 Investment Decisions

The problems that have been outlined arise from the attempt to utilize conventional assessment methodologies for the strategic assessment of new modes of transport. Difficulty in this area derives from the different nature of the questions regarding existing modes. For a new mode, money would be needed for the development of the relevant technology. For existing modes, money can be invested directly in building and operating specific networks in specific places. Much of the information required in each case is the same (i.e., the operational and economic characteristics of the system if it were built), but the assessment of investment in new modes requires a degree of generality that is not necessary with existing modes. Assessment of the total potential market for a new system is needed for the decision on whether or not to invest in developing the system. The implication of this requirement is the need to be able to assess the potential transport systems in a wide variety of urban situations. This is , again ,an area in which relatively little work has been done; the detailed nature of the normal land-use/transportation study has not provided generalized relationships relating travel demand to urban parameters . such work is needed to permit an assessment programme for new modes of transport. The detailed studies which have been carried out can be used to assess the degree to which actual urban situations are amenable to generalization. If this type of approach is successful, the generalized relationships could then form the basis of testing the performance of alternative transport systems. From this information estimates of the potential market for the various systems can be made. This would be the first round in an iterative procedure to account for the effects of economies of scale.

3.4.7 Conclusions and Implications for Simplified Models

It has been shown that conventional four-step procedures are not well adapted to the study of new modes, which might have an important influence on travel. Equilibrium models are better in this respect but more work is needed on the descriptors of user behavior for satisfactory modeling of the effect of new systems on modal split. The shortage of data on non-vehicular traffic is a problem when studying short distance transport systems. The need for assessments of new modes to cover the whole market potential and to include research and development costs make these studies different from those for existing modes and require model results in a range of possible circumstances. For this reason the strategic type of model is particularly important for new mode studies but it is apparent that such models should retain considerable detail with regard to mode characteristics.

3.5 Traffic Restraint

3.5.1 Model Requirements

The study of restraint of traffic either by means of special charges or by physical limitations make particular demands on the models employed. Features which make a traffic model suitable for road traffic restraint studies include:

- a mechanism for re-routing and choice of mode,
- a mechanism for trip generation and suppression,
- sufficient detail as output to allow different types of restraint to be analysed and evaluated on a common basis,
- an adequate description of peak loading and the effect of peak spreaking.

The essential mechanisms that should be provided include:

- provision for differential user responses to charge levels,

- a mechanism to ensure that trip demand changes are consistent with traffic changes.

Desirable features form an extensive list ,but some are of much greater importance and relevance than others; i.e.,

- response of modes of transport to restraint measures affecting them only indirectly;
- the identification of different types of trip and traveler to allow benefit and disbenefit transfers to be studied;
- a specific mechanism to show the effect of physical constraint on trips.

3.5.2 Short and Long Term Effects

Traffic restraint measures have both short and long term effects and the requirements for study differ markedly between these two time scales. Short-term response to traffic restraint measures specifically require a network wide model responsive to "small " and local disturbances at the traffic management scale. Long term responses to traffic restraint require a substantial understanding of the location criteron for activity systems in the area affected directly or indirectly by the restraint measures. It is therefore appropriate to distinguish between long and short term response models by the depth and complexity of the travel generation and distribution mechanism used.

Short term models do not require sophisticated sub-systems concerning activity location and can therefore be greatly simplified in this part: however, the ability to respond to very small local changes with some fair measures of geographical representation is critical to short term problems, and no simplification is admissible that reduces the effectiveness of the geographically–specific balance between supply, demand, and travel responses. Long term models require comparatively little geographically specific network details, and can be drastically simplified in their detailed representation: however the supply, demand, travel response mechanism is trill of central importance, and the activity shifting and altered attractiveness and accessibility sub-models brook no simplification. The underlying distinction between ling and short term models that allows us to simplify in specific areas is the length of time taken for location of activity to respond substantially to the altered conditions .For a brief time span the redistribution of flows and overall reactions on travel demand are central issues: for the longer term the alterations induced in activity patterns take over.

3.5.3 Simplified Models

An example of a suitably simplified model of short term response is the RRLTAP restraint model [18][30][31][91][92]. This adopts a simplified travel demand response sub-model ,but makes stringent demands on the network and travel behavior response sub-models to achieve a high degree of consistent sensitivity and detail in the simulation of locally applied charging policies .The model is described in the references given above and is distinguished from others in the close attention paid to equilibrium balancing of road against road, route against route, and trip costs against trip demands. Restraint models are designed to compare fiscal policies such as parking charges, road pricing in local areas and under different pricing restrictions, cordon charges, and mixtures of all these pricing strategies. As the actual level of charge in each small region of a network under the prevailing limitations on area and type of charge is of considerable importance, a special model for estimating the internal reliability of each network. Benefit figure obtained was needed. With known error bars on each point the reliability of the conclusions drawn from a systematic study of local and overall fiscal restraint policies may be monitored. Other models concerned with a fairly short term viewpoint are the West Midlands Transportation Study (Where parking charges were studied as a means of adjusting the overall level of travel demand), and the use of the SELNEC[53] transportation model to study the effects of traffic restraint .Both WMTS and SELNEC were also concerned with the longer term problems ,and the SELNEC model in particular has a structure suitable for both time scales .However, these models cannot be regarded as "simplified ",as the full apparatus appropriated to a detailed transport planning system was included in both cases . The London Transportation Study introduced a simple and pragmatic model of longer0term traffic restraint; this was carried out by a linear programming procedure and while the results were helpful and indicative, the technique as applied was at that time insufficiently developed to provided a firm basis for forecasting. Of these models the SELNEC one has proved to be that best adapted to a "simplified model "mode of operation.

On line of approach to the overall strategic problem is the CRISTAL model. The prime feature of long term relevance is the demand model used to characterise trip generation and distribution in a manner wholly consistent with the evaluative framework.

This compromise in representation allows the model to be used to study multi-modal policies over the system as one integrated entity, and therefore provides a half-way house between short term and long term models.

3.5.4 Conclusion Regarding Simplification

While the simplifications laid out in 3.5.2 are likely to prove adequate for fiscal restraint policies, physical restriction schemes require more detailed models of the linkage of part-journeys into round tours, as the altered balance of opportunities for activity is not adequately represented in current models. A possible simplification that might be introduced is the complete removal of geographical representation in favor of more detailed analysis of conditional linkages between trips, modes, purposes and activities.

Clearly, both long and short term responses are of importance, and one must be able to analysis both fiscal and physical restraints separately and in combination: if these issues are separated on the lines suggested above, one may use drastically simplified models that may permit the analysis of each situation in an appropriate manner and isolate the vital issues and criteria.

The essential feature of models exployed for the study of traffic restraint should be the incorporation of an explicit demand model in an equilibrium approach which can allow generation, distribution ,modal split and path choice to be all effected simultaneously.

The above issues and simplifications are all essentially cross-sectional or equilibrium view points. Severely simplified models responsive to the interaction through time of location, mode usage ,and travel response may well provide the insights necessary to achieve the objectives determined for a long term response to traffic restraint.

Chapter 4

DATA REQUIREMENT AND SIMPLIFICATION

CHAPTER 4

DATA REQUIREMENT AND SIMPILIFICATION

4.1 Data Requirement

4.1.1 Introduction

Whatever the type of model to be used, those responsible for transport studies are generally faced with two constraints:

- Budgetary constraints due to the fact that the collection of data necessary for the application of the models constitutes one of the most costly elements of the study;

- Constraints as concerns the availability of the necessary information, which can to a certain determine the quality of the models to be used.

It is clearly worthwhile, therefore, to devote a special section to the problem of data needed for application of models, with particular emphasis on the practical aspects involved in transport studies, i.e.:

- What data are needed?

- What type of data?

- How and from what source should they be collected?

- What are the resources needed to collect the necessary basic data?

4.1.2 Data Requirement

In very general terms, data are used at three stages:

- In the development of the models;
- In the calibration of existing models;
- In the application of existing and calibrated models for forecasting purposes.

The first two stages can, however, be combined: If the transport planner does not know a priori which variables will be taken into account by the model, the experience required and the compilation of literature already published on the question will nevertheless enable him to define to a certain extent the kind of information to be assembled. The main problem therefore is the choice of methods of data collection. The technique most often used is random sampling, which is well known and calls for no special explanations here. One might, however, point out that although this technique is relatively simple, its application can prove very cumbersome in practice as it is always possible that the sample may be biased.

As concerns the application of the model(s) for forecasting purpose, the main problem is the projection of the necessary parameters to the target horizon. Forecasting techniques may either be borrowed from other disciplines – demography for example – or they may be specific to traffic studies-forecasting of journey patterns, etc. Other difficulties arise from the fact that the value of certain important parameters are not basic data, but figures resulting from the utilization of transport networks; these can be particularly hard to estimate.

4.1.3 The Type of Data Necessary

The data necessary may be classified in three groups:

- Socio-economic data relating to the area studied;
- Data relating to transport network;
- Data relating to journey patterns.

4.1.3.1 Socio-economic data relating to the area studied

These are, primarily:

- Total and working population and students;
- Composition of households;
- Incomes of households;
- Number of motor vehicles per head of population;
- Employment, with breakdown as appropriate by category – workers or employees – and/or by type of activity – industrial, administrative, commercial;
- School establishments.

These data are necessary not only for calibration, if not development, of models of the present situation, but also for application for forecasting purposes. They must be available for each small subdivision of the area studied.

4.1.3.2 Data relating to transport network

These are essentially:

- Length of routes;
- Journey time over specific routes;
- Capacity of road links;
- Cost of journey along these road-links;
- Parking capacity.

This information is required both for calibration of models applied in a real situation and for the use of these models for forecasting purposes.

4.1.3.3 Data relating to journey patterns

These data are in fact of two kinds:

- Factual data relating to travel under the prevailing conditions;
  - Number of journey per day per person or per household;
  - Trip purpose at origin and destination;
  - Geographical origin and destination of journey;
  - Time of departure and journey time;
  - Mode(s) of transport used.
- Parameters representing the probable behavior of the individuals concerned in

the future.

These parameters are those included in the mathematical relationships constituting the models used, relating the characteristics of travel as indicated above to the socio-economic data of the area in question and the characteristics of the transport network serving it.

4.2 Data Simplification

4.2.1 Introduction

One way in which simplification can be brought about in current urban traffic models is through changes in the data collection and analysis stages. These changes can be obtained in the two main ways described in the remainder of this section.

4.2.2 Aggregation

Aggregation means combining several elements of models in order to reduce the number of items to be explicitly analysed.

This provides an apparent increase in accuracy and may well be necessary to eliminate the misleading biases which can occur in highly disaggregated information. However, for strategic studies which are frequently concerned with policy issues, there is a tendency to require information on the effects on particular sectors of the population. Thus, the objective of simplification in order to have flexible strategic models tends to conflict with the requirement for this information and a compromise is necessary to keep data requirement within limits. It is important to be sure that segmentation, if adopted, is relevant to the output required and does not stress the input data unduly since a very efficient direction for simplification involves the suppression of irrelevant segmentations.

- Aggregation of market segments
- Aggregation of zones
- Network aggregation

4.2.3 Omission of Variables

The obvious way to simplify models is to omit certain variables. For example, in the case of level of service, instead of a number of variables, ignore cost, frequency of service, walk distance, etc. , and include only travel time. This amounts to assuming zero elasticities for the omitted service variables.

In some towns it may be possible to omit public transport analysis; in others, car parking analysis may be simplified.

Obviously, omission of variables can lead to serious biases in the results in some cases, and be perfectly acceptable in others. Each case must be judged on its merits.

4.2.4 Concluding Remarks

Each urban traffic models is the result of a balance between resources allocated to model formulation, data collection, model calibration and the testing of alternative transportation strategies. Several methods on simplification of data during model calibration, data collection has been discussed above. But in order to make the accuracy of the result to be acceptable, the best way is to outline normal data requirement (see section 4.1), ways in which data could be simplified, or have been , and accuracy consideration influencing observed (and theoretical) accuracy levels from various studies.

Chapter 5

APPLICATION OF STRATEGIC MODEL IN RDS STUDY

CHAPTER 5

APPLICATION OF STRATEGIC MODEL IN RDS STUDY

5.1 Introduction

To sustain the economic growth and quality of life in the Shenzhen Economic Special Zone (SESZ) as the SESZ has experienced massive demand for private person travel and goods vehicle movements in the last ten years, a Comprehensive Transport Planning and Railway Development Study(RDS) has just been finished.

SESZ is the most typical city in China, which has very high-speed economic and urban development. Since 1980, along with the economic reform introduced in China, SESZ has developed from a small village with only 10,000 population to a large city with over 1.5 million people and the rate of the urban development is keeping high.

The transport planning in SESZ is very difficult to operate due to lacking of basic data, great changes of land use and sharp increases of population. So during the whole RDS study period, the strategic transport planning model developed by this research has been applied and some effective and useful results have been achieved.

5.2 Data Requirement and Collection

5.2.1 Modelled Years

Models are being applied for the following years:

- Model validation – 1999;
- Design Years – 2010 plus 'long-term' forecasts

5.2.2 Planning Data

2010 planning data are mainly from the Masterplan and the District Plans of SESZ. Because the District Plans assumed a much higher population growth within the SESZ between 1999 and 2010 than had been assumed in the Masterplan, so the District Plan planning data have been utilised as the best available for year 2010 as they represent the most up to date forecasts.

The planning data from the District Plans was available at a level of disaggregation of 113 zones within the SESZ and 20 zones outside the SESZ. This zoning system was thus adopted for the Comprehensive Transport Planning (CTS) model, with a further 17 "external" zones (including a number of special generators within SESZ, e.g. the airport) being defined. Thus the CTS model was defined with a total of 150 zones.

A finer zone system is required for the Railway Developement Study (RDS) model to replicate in more detail the accessibility of individual zones to rail stations. A total of 463 zones have been defined in the RDS model – 279 within the SESZ and 167 outside the SESZ, plus the same 17 external zones as in the

CTS model.

Total population data for each zone was directly extracted from the District Plans. For each zone, the percentage of this total population that is "permanent" and the percentage that is "temporary" was then estimated, and the permanent population further disaggregated into those living in "households" and those living in "collectives".

The District Plans did not include employment forecasts and these have been developed from land use data. This has been achieved through application of established factors to the gross floor area for three types of land use type as set out in the District Plans: industrial; commercial and office. These in turn were used to develop estimates of trip attraction and trip generation.

No planning data is available for time horizons beyond 2010. It has thus been agreed that global factors should be applied to 2010 levels and patterns of trip making – to 2020, or 2030 as appropriate.

5.2.3 Special Generators

Information has also been collected on the location, size and capacity of special generators within the study area, including:

- Shenzhen International Airport (with 12 hour traffic counts undertaken for all turning movements between the airport access road and National 1 and the Guandong Expressway);
- Hong Kong passenger border crossings (daily and hourly passenger crossings

at LoWu were extracted from KCRC records);

- Hong Kong vehicle border crossings (daily and hourly vehicle crossings at Lok Ma Chau, Man Kan To and Shau Tau Kok were extracted from KCRC records);

- Port Movements (the throughput of the ports of Yantian, Shekou and Chi Wan was extracted from our own data sources);

- Main Freight Terminals (the location and size of the main freight terminals inside the SESZ and outside the SESZ was determined).

5.2.4 Data from the 1995 Shenzhen Household Interview Survey

5.2.4.1 Trip Generation Data

The trip generation data was derived from a detailed assessment of the Household Survey undertaken in 1995. A large number of additional tabulations to those reported in the original report were specified to establish trip rates for the specific categories as specified for the study. It was recognised that, based on experience in other studies, household surveys generally under-report levels of trip making, often by a substantial margin, and hence that the number of trips derived from the household survey may be under-estimated.

5.2.4.2 Trip Distribution Data

Average trip lengths (measured in terms of journey time) and trip length distributions for a number of sector to sector movements were derived from the 1995 Household Survey. This information will be used in the model calibration and model validation stages.

5.2.4.3 Mode Split Data

The main mode split between private (car and taxi) and public (bus) modes was originally derived by the mode choice information contained in the 1995 Household Survey. The modelled main mode split will be validated against that observed by comparing private and public passenger flows across screenlines - see bus and vehicle occupancy count sections below.

5.2.4.4 Peak Hour Data

The daily-to-peak hour factors applied in the CTS model were initially developed by purpose and broad sector-to-sector movement. Refinement to this data was undertaken in order to replicate the observed movements across screenlines.

Note that this data is directly from the interview survey and is being reviewed (and modified) for the purpose of model calibration.

5.2.5 Highway Network Data

The highway network within the SESZ was checked and updated and the network was extended to cover the area outside the SESZ.

Each link within the network has been coded with:

- Link type and classification;
- Link length;
- Number of lanes;
- Link capacity; and

- Volume Delay Functions - vdf - (i.e. speed-flow relationship) which defines the highway speed for a given volume/capacity ratio e.g. free flow link speed, speed at capacity and delay over capacity.

As part of the CTS model development, a thorough review was made to the calculation of highway capacity and the definition of speed flow curves in order to fully represent the effects of congestion.

Bus lanes were also coded and their effects on both bus and car speeds modelled.

5.2.6 Public Transport Network Data

A public transport assignment model has been developed as part of the study. The base year model consists of bus services coded onto the relevant highway links, and requires the following data:

- The detailed routing of each bus service;
- The average frequency of each bus service;
- The fare schedule for each bus service;
- Travel times for a representative sample of routes; and
- The capacity of each bus type.

Details of bus service routings, frequencies, fares and end-to-end journey times for services wholly within the SESZ, and for cross-boundary services crossing the SESZ border, have been obtained. It has proved more difficult to obtain reliable information on minibus services outside the SESZ, where they tend to be operated on a more informal basis. Assumptions were made where data was not available.

5.2.7 Observed Data for Model Validation

Observed data is required for model validation. Six items of observed data were collected:

- vehicle counts;
- bus occupancy surveys;
- vehicle occupancy surveys;
- bus journey time surveys;
- car journey time surveys; and
- bus operational data.

The collection of each of these 6 data items is described in turn below.

5.2.7.1 Vehicle Counts

Vehicle count surveys were undertaken at a total of 64 locations within the study area: 45 sites within the SESZ and 19 locations outside the SESZ. The site locations were defined so as to capture all the major trip movements within the study area.

At each survey site, cordon point vehicle counts were undertaken in both directions for each 15-minute period, sub-divided by vehicle type as follows:

- Private cars/taxis
- Van
- Truck
- Public minibus
- Public bus
- Private bus (e.g. company bus)

As part of model validation, these individual count sites were aggregated to form a series of cordons and screenlines as experience suggests that this forms a more robust basis for model validation. The 45 count sites within the SESZ were aggregated to form 12 screenlines and the 19 count sites outside the SESZ were aggregated to form 9 screenlines.

5.2.7.2 Bus Occupancy Surveys

To assess bus passenger flows, bus occupancy surveys were undertaken at 21 of the 64 vehicle count sites identified above. These 21 sites were identified as locations which carried the greatest amounts of public transport trips. 17 sites were located within the SESZ and 4 outside the SESZ. The locations of the bus occupancy surveys are illustrated in Figure 3 (inside the SESZ) and Figure 4 (outside the SESZ).

There are practical difficulties in accurately counting the number of people on board individual buses, and also recording the details of the individual buses themselves (line number, vehicle type etc.). The aim was therefore to record data for a high proportion of buses such that average vehicle occupancies for individual bus lines and/or cordon points could be estimated to a reasonable level of accuracy. These averages were then applied to bus data derived from the vehicle count surveys to provide an estimate of total bus passenger flows at each survey point.

Buses were classified into a number of generic types for the purpose of the survey (e.g. minibus, single-deck bus, articulated single-deck bus, double deck). Loadings for each bus were similarly estimated by reference to the proportion of seats occupied, or where passengers were standing, by reference to the broad level of crowding. From a knowledge of capacities for each generic vehicle type (by observation), the estimated load for each bus could be derived.

Table 5-1 Loading Classification used in Bus Occupancy Surveys
'Factor' is applied to the Seating Capacity of the bus

Class	Factor	Description of Loading
1	0	Empty
2	0.25	<50% seats occupied
3	0.5	>50% seated
4	0.75	All seated
5	1	Comfortable standing
6	1.5	Capacity
7	2	Overflow

Table 5-2 Assumed Capacity of Buses (Passengers)

Type of Bus	Seating Capacity	'Crush' Capacity
Single Deck	40	80
Minibus	20	40
Articulated SD	50	100
Double deck	60	120
Midibuses	30	60
Other	30	60

5.2.7.3 Vehicle Occupancy Surveys

The surveys showed that average car occupancy is 2.0 persons (including the driver). No major surveys of average taxi occupancy were carried out, but a set of limited observations showed the overall average (i.e. including empty taxis) to be two people per vehicle – the driver and one passenger, and this has been carried forward in our modelling work.

5.2.7.4 Journey Time Surveys

- Bus

  Bus journey time surveys were undertaken in the PM peak period and during an off peak period on 5 routes. In addition, some sample information has been obtained from the Shenzhen Bus Company on actual (as opposed to scheduled) running times for selected bus lines.

- Car

  Car journey time surveys were also undertaken (in PM peak and off peak conditions) along the routing of the 5 bus services defined above to ascertain car journey times along these routes.

5.3 Modelling and Calibration

5.3.1 Planning Data Forecasting

5.3.1.1 Forecasting Process

The future year level and distribution of population and employment will primarily determine the rail development strategy of Shenzhen. Planning data forecasts are therefore a primary input (required by CTS zone and by RDS zone) for the base year and future years. The planning data inputs include:

- Population by residential category (household-based or collective);

- Employment by category (commercial/retail, office, industrial)

A summary of the approach to the planning data forecasts is shown in Table 5-3. For ease of reference, the inputs/outputs of each element of the CTS model adopt a common numbering system through subsequent chapters.

Table 5-3 Planning Data Overview

Inputs		District Planning data by legal zone Data for base year (1999) and forecast years (2010)
Methodology		Disaggregation to CTS/RDS zones based on available information
Outputs	1	Population by household / collective by CTS/RDS zone
	2	Jobs by category (industrial/office/commerce) by CTS/RDS zone
	2a	Number of households by CTS/RDS zone
Issues		Strategic issues – interaction of land-use and rail networks, including the effect of the second SESZ boundary Comparison of data from MasterPlan with more recent data by district for the SESZ Floating / Temporary population is not included Base year for planning data is 97 (some earlier) not 1999 Planning data for 2020 is not directly available

5.3.1.2 Methodology

The base year data has been derived from the most recently available sources. Within the SESZ the data is taken from the District Plans which related to 1997. Outside the SESZ, some of the data was collected in 1995. For model validation, a 1999 dataset was derived by interpolation between 1997 and the 2010 forecasts and is summarised in Table 5-4.

Table 5-4 Base and Future Year Population Data

Population Sector	Type of Hhd	1997	2010	Diff All Pop	% Diff All Pop
SESZ	Hhd	1,076,000	2,383,000	1,307,000	121%
	Collective	754,000	400,000	-354,000	-47%
	Total	1,830,000	2,783,000	953,000	52%
XSESZ	Hhd	735,000	1,844,000	1,109,000	151%
	Collective	1,314,000	656,000	-658,000	-50%
	Total	2,049,000	2,500,000	451,000	22%
All	Hhd	1,811,000	4,227,000	2,416,000	133%
	Collective	2,068,000	1,056,000	-1,012,000	-49%
Grand Total		3,879,000	5,283,000	1,404,000	36%

Source: Compiled for CTS/RDS Study (based on District data for SESZ and MasterPlan for outside SESZ

Note: Planning data forecasts are summarised by District in Appendix B for 1999 and 2010.

For the future years, it had originally been our intention to use the 2010 planning data contained the present study undertaken in 1996. However, this data has not been formally approved, and the planning assumptions in District Plans had, in a number of cases, been substantially revised. Consequently, the data used in the 1996 CTS was not adopted as a basis for the demand modelling.

Accordingly 2010 population forecasts contained within District Plans have been used in model development; employment forecasts have also been derived from District Plans, using established multipliers applied to floor areas for individual land use types.

For the SESZ, the District Plans show significantly higher forecasts of population growth than the Shenzhen Master Plan. Outside the SESZ, the District Plans are from the same source data as the Master Plan and so no differences are apparent.

5.3.1.3 Summary of Forecasts

Population forecasts are shown in Table 5-4. Within the 36% overall increase in population - 1.4 million additional persons – there is a significant shift from population resident in collectives to those resident in households. Overall growth is higher within the SESZ (52% or 0.95 million people) is greater than outside the SESZ (22% or 0.45 million people).

5.3.1.4 Special Considerations

Strategic Issues – Future year planning data by CTS and RDS zone will primarily determine the rail development strategy. At the same time, the future rail development strategy will undoubtedly influence the distribution of population and employment. The policy regarding the second boundary across the SESZ could also profoundly affect land use planning and the distribution of population and employment.

For the Study, the distribution of population at the CTS level will be used as a reference case. However, rail network development options requiring amendments to this input data will not necessarily be discounted. In such cases the broad planning thresholds (population/employment levels) necessary to support these options will be investigated. The distribution of population/employment *within* each CTS zone (i.e. in the disaggregation for the RDS model) will be estimated with due regard to the focus of activity that a rail station provides.

Comparison with MasterPlan – A comparison of the Masterplan forecasts and those compiled in the Study is given in Table 5-5 below. Note that for areas outside the SESZ, the forecasts are both based on the MasterPlan so no differences are evident. Inside the SESZ, however, large differences are evident, particularly for Nanshan District which accounts for around 56% of population growth within the SESZ.

Table 5-5 Population Forecasts for Year 2010 - Comparison with MasterPlan

Sector	District	1997	2010 MasterPlan	2010 RDS/CTS	Diff. CTS-MP	% Diff Diff/MP
SESZ	Lo Wu/Futian	1,254,000	1,145,000	1,554,000	409,000	36%
	Nanshan	466,000	469,000	1,029,000	560,000	119%
	Yantian	110,000	180,000	200,000	20,000	11%
Subtotal	SESZ	1,830,000	1,794,000	2,783,000	989,000	55%
	XSESZ	2,049,000	2,502,000	2,500,000	-2,000	0%
Total		**3,879,000**	**4,302,000**	**5,283,000**	**981,000**	**23%**

Long Term (Year 2020) Planning Data –No population or land use forecasts are available for the longer term beyond 2010. It has therefore been agreed with SUTPC and Planning Department that long-term population and employment will be derived by application of global factors to the 2010 forecasts. Areas of particular growth potential can be reviewed on a pragmatic basis.

Floating Population – The land use data does not include short-stay population such as tourists, business travellers and very short-term migrants. Some allowance will be required in the trip-end model for this deficiency.

Household Size – The average household size from the 1995 Home Interview Survey is 3.3 persons for the SESZ and 3.5 for outside the SESZ. Forecast data for future years is not readily available. The exclusion of household size and composition (workers, students, other) as an explanatory variable in the forecasts has been investigated further with relation to household income/car availability and trip-rates. The conclusion is that household size can be omitted from the planning inputs as total trips per person is not strongly related to number of persons in the household.

5.3.2 Trip End Models

5.3.2.1 Overview

The trip end model produces forecasts of the level of total daily person trips by all mechanised modes. The trip end forecasts comprises three components:

- Income forecasts
- Car availability forecasts
- Trip Generation forecasts (trip generations and attractions)

The trip end model aims to include the major 'explanatory variables' that will contribute to increased personal travel in future years. The primary determinants in forecasts of increased personal travel will be (i) higher levels of population and employment (with a lower proportion of collective residents) and (ii) increased personal income (leading to increased car ownership, trip-making, and greater use of mechanised modes).

Specific considerations with regard to the trip-end models include:

- Population living in collectives is treated separately from other population (largely household-based) due to the low overall mechanised trip-rates for collective residents

- Population resident in households is available by permanent residents and temporary residents for the base year. Temporary residents have lower observed mechanised trip-rates (and lower car-ownership) than permanent residents. However, these two groups are combined due to the difficulty of forecasting the future permanent/temporary household split by area.

- Primary trip rates are applied by 3 broad areas – (i) SESZ1 (Lo Wu and part Futian), (ii) SESZ other and (iii) outside SESZ. Further refinement of trip-rates at a local level is also required to achieve a satisfactory validation.

5.3.2.2 1995 Home Interview Survey

The initial model forecasts will be based on the 1995 Home Interview Survey undertaken by SUTPC. This survey covered all aspects of trip making including the characteristics of the trip-maker (resident type, available mode, age, household income etc.) and of the trip (purpose, origin and destination, mode, and destination/arrival time).

An overall summary is given in Table 5-6, which highlights the low level of trip making, particularly for mechanised modes. Around 50% of all residents are recorded as not having made any significant trips - (walk trips of less than 500m were excluded from the survey). For comparison, the 1992 CTS-2 Study for Hong Kong found an equivalent mechanised daily trip rate per person of 1.8, compared to the 0.6 for residents of Shenzhen households.

Table 5-6 Summary of 1995 SUTPC Home Interview Survey
Daily Trip Rates Per Person (One-way trips)

Dwelling Type	Total Persons in Survey	No. of Trip Makers	All Modes		Mechanised Modes	
			Daily Trips	Trip Rate	Daily Trips	Trip Rate
Household	17,379	10,730	30,329	1.75	10,084	0.58
Collective	9,973	3,677	10,246	1.03	1,860	0.19
Total	**27,352**	**14,407**	**40,575**	**1.48**	**11,944**	**0.44**

In order to reproduce observed person movements across the surveyed screenlines (total daily persons, all mechanised modes) amendments were made to the above trip rates. The proposed trip rates for use in the study (subject to further refinement) are discussed further.

The need to significantly adjust the trip rates from the survey data is unsurprising due to several factors:

- the survey data relates to 1995 and so does not reflect the significant demographic, economic and car ownership growth since that time;

- household surveys of this type have tended historically to under-report certain categories of trips. Short trips, non-regular trips and non-home based trips are particularly poorly recorded due to respondent error. For example the 1992 Travel Characteristics Study in Hong Kong estimated that overall trips were under-reported by 30% (in comparison to the control screenline counts) and the trip rates were adjusted accordingly;

- the methodology for transforming the trip categories in the household survey (i.e. described by origin/destination rather than production/attraction) gives precedence to HBW trips;

- aspects of the data, such as household income, although aggregated into broad bands, may not have been accurately recorded by the interviewee.

The level of the adjustment required and the low proportion of mechanised trips suggests that a significant update to the 1995 survey may now be warranted. In this event, the survey coding would most usefully be consistent with the CTS model zoning system. This link would allow observed journey characteristics (journey time, mode choice etc.) to be linked to the modal travel costs produced by the model. Further calibration of the model components (particularly the cost models and main mode split model) would then be simplified.

5.3.2.3 Household and Personal Income (Values of Time)

Forecasts of personal income growth are required for two reasons:

- Effect of income on trip making levels – predictions of the proportion of households within each of the three income bands are required by the trip generation model. The annual household income bands (in 1999 prices) used in the trip generation model are (i) less than 30,000 RMB (ii) 30,000 to 50,000 RMB and (iii) over 50,000 RMB.

- Cost and Assignment Models - to predict the changes in passenger and driver Values of Time (VOT). Values of time are defined in terms of money per unit time and define the perceived importance of money in relation to travel time.

The public transport value of time for passengers is particularly important for predicting the split between the proposed Metro system and the generally less expensive bus network.

Table 5-7 Income Model Overview

Inputs	2a	Average base year annual income Proportion of households in each income group by sector/district from the household survey Future year growth in GDP Number of households by zone
Methodology		Establish household income growth by zone Establish control growth total for average household income
Outputs	3	Percent of households in each income group by zone Changes in values of time for assignment
Issues		Household income is closely related to size of households (num. of people) Only three main income groups – continuous data and the average household income of each income group is not available Reporting accuracy may not be high plus the data requires some estimation for base year and future year

The importance of income is clearly demonstrated by the SUTPC 1995 Household Interview Survey in the comparison of trip-rates per person for households of equal size and in the proportion of trips made by mechanised modes. Note, however, that the relationship between trip-making and personal income must be undertaken for households of equal size due to the positive relationship between household size and income (households with more residents generally have larger incomes).

It is recognised that the income data from the household interview survey provides only a broad indication of current income levels as the data is now somewhat outdated and is subject to data capture difficulties. Five household income categories were defined within the household interview survey as follows: <20,000 RMB/year, 20,000-30,000, 30,000-50,000, 50,000-100,000 and over 100,000 (in 1995 prices). However the majority of households fall within the lower two bands (lower three bands for the SESZ1 area). Outside the SESZ, 67% of households are within the lowest group (<20,000 RMB/year). This inevitably represents a limitation on the use of income as an explanatory variable in the trip end model and, should more recent trip-rate data become available, this aspect should be reviewed.

Base year (1999) household income forecasts were developed and the distribution of households within each of the three income groups for each CTS zone was estimated using the 1995 household interview survey. Future year (2010) household income forecasts were derived from the GDP forecasts and overall population growth. A summary of household income is given in Table 5-8.

Table 5-8 Summary of Annual Household Income Forecasts
(1999 Prices)

Year	Area	Household Income Band			Number of
		<30,000 RMB / year	30,000-50,000 RMB / year	Over 50,000 RMB / year	Households
1999	SESZ	50%	29%	20%	346,985
	Outside SESZ	64%	25%	11%	209,981
	All Shenzhen	56%	28%	17%	556,966
2010	SESZ	6%	17%	77%	669,552
	Outside SESZ	14%	31%	55%	438,086
	All Shenzhen	9%	23%	68%	1,107,638

Values of Time for Assignment

The base year values of time (which should relate specifically to trip-makers within the overall population) were derived based on surveyed values from elsewhere and estimates of local conditions such as average household income. Six values are used within the model segregated by car-available/non-car available and by low/medium/high categories. The initial assumed values range from 10 cents per minute (6 RMB/hour) for the low income, non-car available category to 40 cents per minute (24 RMB/hour) for the car available high income category.

Growth in the values of time will be forecast based on GDP growth per capita for Shenzhen. It is recommended that sensitivity tests regarding future year values of time be conducted in order to assess the sensitivity of the sub-mode split model (choice of rail or bus) to this important input.

5.3.2.4 Car Availability Model

Car availability levels will affect the level of service of the future year highway network (travel speeds) which in turn will influence the main mode split (diversion from car to public transport and especially rail) and sub-mode split (diversion of passengers from buses to rail) forecasts. The approach to the car availability forecasts is given in Table 5-9.

Table 5-9 Car Availability Model Overview

Inputs		Total car/taxi fleet size (i.e. policy test) Percentage of households in each income group by zone
Methodology		Determine base year distribution of cars according to income and area
Outputs	4	Proportion of households with no car, or 1+ cars by zone
Issues		Include private car and company car. Exclude motorbike from car available Availability of base year data for model calibration Area is used as a proxy for accessibility and parking supply Cost of car ownership and up-keep is excluded as an explanatory variable

It is proposed that the total car fleet size (for personal cars and company cars combined) is input as a 'policy' control and that sensitivity tests are undertaken to determine the impact of changes in this assumption. The alternative approach of 'forecasting' the car fleet size based on income and costs (i.e. without policy control) is not recommended due to the potentially very large fleet size which may result and the difficulties of forecasting the cost inputs required.

Initial forecasts of growth in private car ownership in Shenzhen give a total of 467,000 cars compared to 121,000 in 1999. This represents an increase of around 14 percent per annum.

5.3.2.5 Trip Generation Model

Table 5-10 Trip Generation Model Overview

Inputs	1	Planning data by zone
	2	Jobs by category: industrial / office / commercial
	3	Percent of households in each income group by zone
	4	Percent of households with no car, 1+ car
Methodology		Define trip-rates by income, purpose and car-availability (CA/NCA): In total - 13 groups – 7 categories by car-available and non car available Includes all mechanised trips over 500m i.e. excludes walk/cycle Explanatory Variables Planning Data Household Income Area
Output	5	Daily generations (all modes) by trip category and car-availability by zone
Consider		Insufficient data to calibrate distribution/main mode split for each category Area used as a proxy for accessibility Convert 1995 Home interview data from survey categories to those above (e.g. all-home is not directly applicable etc.) Suspect trip-rates include significant under-reporting of certain trips Forecast mechanised trips – exclude walk/bicycle trips

The trip generation model will initially be calibrated on an aggregate basis from the 1995 Home Interview Survey database. Separate trip rates (for mechanised trips) will be developed by trip category, by car availability group, by income and by area. The alternative approach of disaggregate regression-type models (i.e. developing a single continuous equation to include all variables) is not supported due to the lack of sufficiently reliable and detailed survey data.

Some further estimation will be required to convert the data from the purpose groups in the household survey (based on trip Origin/Destination) to the trip

Production/Attraction format specified above. In particular, the Everywhere-Home category will be re-distributed amongst other categories.

As discussed above, the initial CTS model runs comparison of total modelled person screenline person crossings against the observed values highlighted the need to adjust the values from the home interview survey. The proposed trip rates (subject to further minor refinement) are shown in Table 5-11.

Table 5-11 Proposed Daily Mechanised Trip Rates for 1999

Comparison with Hong Kong and Shanghai

Trip Purpose	**Trip Rate Per**	**1986 Shanghai**	**1992 HK**	**1999 SESZ**	**1999 XSESZ**	**1999 Shenzhen**
HB Work	Worker	0.78	1.41	1.40	0.86	1.19
HB School	Student	0.19	1.08	0.70	1.07	0.82
HB Other	Person	0.16	0.61	0.41	0.27	0.35
NHB	Person	0.09	0.20	0.19	0.11	0.16
ALL	**Person ex. COL**	**0.66**	**1.81**	**1.42**	**0.88**	**1.20**
COL	COL Resident	n/a	n/a	0.70	0.19	0.38
ALL	**Person ALL**			**1.17**	**0.48**	**0.81**

Note: Shenzhen residents divided into households and Collectives (COL). Not available from Shanghai or HK

HB – Home-based; NHB – None Home Based

NHB includes Employers business (EB) and other purposes

Source: Shanghai Urban Transport Analysis and Forecasts, 1998

Hong Kong – CTS Model Enhancement Study Final Report, 1995

For detailed model calibration, small local adjustment factors were applied to the trip-end model by sector.

5.3.2.6 Trip Attraction Model

In common with standard practice, the overall level of attractions will be controlled to forecast total trip generations by purpose. Hence the model must provide the relative importance of each of the explanatory variables in forecasting trip attractions. However, suitable locally observed data for calibration of the trip attraction model is not directly available. Moreover, there is also a lack of (particularly forecast) information on employment by detailed land-use category (i.e. retail, commerce, leisure, office by type – finance/government etc.).

Two methods are proposed to address the deficiency in survey data and detailed planning forecasts as follows:

- For HBW, HBO and NHB trips, the generations will be distributed according to attraction-rates surveyed elsewhere (e.g. Hong Kong) for similar categories of employment. Home-based work trip attractions will be distributed by the location of employment by category. Home-based Other (HBO) and Non-home based (NHB) trip attractions will be distributed according to Commerce and Office employment. In all cases a weighting for central area jobs will be applied as such areas will attract a higher proportion of mechanised trips than others; and

- For Home Based School (HBS) trips and trips made by residents of collectives (COL), forecasts of trip attractions are not required as the trip distribution will be undertaken using a 'singularly' constrained distribution model. In this approach, trip generations are distributed based on trip length and attraction trip-ends (e.g. schools and collective work places) are assumed not to be a constraint.

Supplementary data to calibrate the trip generation/attraction and distribution model includes trip-length by purpose from the interview survey and total daily person screenline crossings (although this is only available for all purposes combined).

Table 5-12 Trip Attraction Model Overview

Inputs	2	Jobs by category industrial / office / commerce by zone
Methodology		Control total attractions totals to generations – hence only distribution of attractions important HBW trips distribute by employment data HBS attractions not required – distribute by trip-length (mins) HBO trips based on employment – particularly commerce NHB as HBO, NHB – generations as attractions COL attractions not required – distribute by trip length (mins)
Output	6	Daily attractions (all modes) by category and car-availability by zone
Issues		Area must be used as an explanatory variable Surveyed trip attraction rates are not available

5.3.3 Network Cost Models

5.3.3.1 Highway Cost Model

For this rail development study, the highway cost model is used primarily to forecast highway speeds and bus travel times. Thus the highway cost model must produce realistic travel times for a given level of traffic flow which requires careful review of link capacity and volume delay functions (VDFs).

Table 5-13 Highway Cost Model Overview

Inputs	(11) 7	Initial peak hour PV vehicle trip matrix Initial peak hour GV vehicle trip matrix EMME/2 Highway network including bus preloads volume delay functions Misc. info by zone Highway tolls Taxi fares Car distance related costs – fuel value of time information – CA / NCA vehicle occupancy
Methodology		Skim time and distance from assignment Manipulate to zonal generalised cost
Output	8 8a	zonal matrix of highway travel time and money cost (private car) zonal matrix of highway travel time and money cost (taxi) EMME/2 network – highway link speeds for bus speeds
Issues		Definition of capacity and volume/delay functions Parking charges not included

Multi-routing (equilibrium) highway assignments are undertaken. All aspects of highway costs are included within the cost model and include tolls, taxi fares and vehicle operating costs and network travel times. For assignment, the money values (tolls and vehicle operating costs) must be converted to equivalent minutes in order to calculate routings based on generalised journey cost.

The following data is extracted (i.e. skimmed) for each origin-destination pair in the form of a zone to zone matrix:

- Average total generalised cost

- Average distance traveled

- Average toll paid (in minutes)

For assignment, the middle-income values of time are used to convert from money to time units. Subsequent to assignment, the middle-income travel times (minutes) and travel costs (cents) are calculated based on the above three data matrices. In the calculation of generalised cost by trip category (car available/non-car available by trip purpose), the travel times and travel costs are again converted into minutes using the appropriate value of time (i.e. low/medium/high).

This approach accounts for differences in values of time between trip categories but reduces model run time through limiting the number of assignments required. In this way, the effect of tolls or taxi fares is better represented as, for example, low income non-car available trips are less likely to use a taxi than the equivalent high income trips.

5.3.3.2 Public Transport Cost Model

Within the CTS model, the primary purpose of the Public Transport (transit) assignment is to ensure that travel costs are properly represented. These travel costs are then used in the main mode split and sub-mode split models. As the RDS model will be used to assess detailed assignment results (i.e. passenger loadings and routeings), these aspects are less important within the CTS model, provided that the various routes selected are not significantly different in terms of cost. The overview of the Public Transport Cost Model is provided in Table 5-14.

Table 5-14 Public Transport Model Overview

Inputs		Initial peak hour trip matrix EMME/2 network following highway assignment Travel time functions Value of time information – NCA
Methodology		Convert fares to times using VOT Calculate bus speeds based on highway speeds Skim GC from assignment
Output	9	Zonal matrix of public transport generalised cost
Issues		Calculation of bus speeds from highway speeds Include effect of bus lanes Fare levels for future years – rail and bus Future year bus/minibus routes – level of rail competition

There are three main determinants of public transport costs:

- The scheduled coverage and frequency of services;

- Fare levels (converted to generalised cost minutes based on values of time); and

- The in-vehicle run-times which, for bus, are dependent upon highway speeds.

The first two data elements are taken from published sources and are an external input to the EMME/2 model (i.e. do not change within a model run). The bus travel times, however, are calculated based on the modelled highway speed and are calibrated against observed sources. This approach is adopted in order to represent more accurately any forecast changes in future year bus speeds either through highway improvements (quicker buses) or traffic congestion (slower buses).

To convert from highway speeds to bus travel times, a total of between 1.2 and 1.5 minutes per kilometre is added to represent the additional delay at bus stops. This approach is preferable to simple factoring of highway times (i.e. bus speeds are around 60% to 70% of highway speeds) as the differential between highway and bus times is relative smaller in cases of high congestion. The effect of bus lanes is also included within the calculation through the use of a minimum bus speed and of a lower delay per kilometre.

As in the highway cost model, the assignments are undertaken using the middle income (non-car available) values of time to convert fares to equivalent minutes. Assignments are then undertaken and the following data is extracted for each origin-destination pair:

- Total generalised cost (travel time plus fare in minutes)
- Fare (minutes)

Travel time in minutes (excluding fare) is then extracted and the fare matrix is converted back to money values (cents). In the calculation of generalised cost by trip category (car available/non-car available by trip purpose), the travel times and travel costs are again converted into minutes using the appropriate value of time (i.e. low/medium/high).

This approach ensures that low income households and trip-categories are more sensitive to the effect of fares than high income households. For rail forecasts, this sensitivity is vital as (i) rail fares tend to be higher than equivalent bus fares but (ii) income levels are forecast to increase significantly higher than real fare levels.

5.3.4 DISTRIBUTION, MAIN MODE SPLIT AND PEAK HOUR MODELS

5.3.4.1 Distribution Model

The trip distribution model determines how the trip generations and trip attractions from the trip end model are linked to form trips. A gravity model will be adopted for this purpose whereby the proportion of trips between two zones decrease with increased travel cost. As mechanised trips only are included within the distribution model, a 'friction function' is required to account for short-distance trips that would otherwise be made by walk or bicycle modes. An overview of the distribution model is shown in Table 5-15.

Table 5-15 Distribution Model Overview

Inputs	5+ 6 8 9	Daily trip-ends generations/attractions (all modes) by category and car-availability by zone Zonal matrix of highway generalised cost Zonal matrix of public transport generalised cost Observed trip lengths by mode and purpose Daily person screenline crossings
Methodology		Calculate proportion of trips by mode for each O-D pair Calculate four categories distribution of trips to/from zone based on generalised travel cost: CA PV, CA PT, NC PV, NC PT. Home-based school (HBS), Collectives (COL) are singularly constrained HBW, HBO and NHB are doubly-constrained (furnessed to both trip generations and trip attractions)
Outputs	10 a	Daily Production/Attraction Trip Matrices by Purpose and Car Availability

The general form of the distribution function is as follows:

$$T_{ij} = P_I * \frac{A_j * FF * (GC^{\wedge a} * e^{(b * GC)})}{\sum A_j * FF * (GC^{\wedge a} * e^{(b * GC)})} \qquad (5\text{-}1)$$

where:

T_{ij} = trips for any i-j pair

P_I = productions in zone I

A_j = attractions in zone j (equal to 1 for HBS and COL purposes)

FF = friction function (minutes) related to distance

GC = generalised travel cost utility (minutes - including time and money cost)

a = calibration parameter

b = calibration parameter

and the utility function is as follows:

GC (mins) = travel time (mins) + travel cost (mins)

where

travel cost (mins) = money (cents) * Value of time * scaling factor

The values of time differ by Car availability group (CA and No CA) and by trip purpose. Thus the distribution model is run a total of 26 times as follows:

7 No Car Available Public Transport trips, (7 purposes)

7 No Car Available Private Transport trips, (7 purposes)

6 Car Available Public Transport trips, (6 purposes)

6 Car Available Private Transport trips, (6 purposes)

Each model has calibrated constants to give the appropriate trip length form and distribution. The scaling factor is used to determine the relative importance of money and travel time in the trip distribution decision. The principal data for calibration of the trip distribution model is the trip-length by purpose from the home interview survey and the observed total daily person screenline crossings (although this is only available for all purposes combined).

As discussed in the Trip Attraction model, two forms of the distribution model are used depending on the trip category. For HBW, HBO and NHB trips, both the productions and attractions from the distribution model will be constrained to the trip end model forecasts using a furness procedure (i.e. a doublely constrained gravity model.) However, for Home Based School (HBS) trips and trips made by residents of collectives (COL), the trip distribution will be undertaken using a 'singularly' constrained distribution model. In this approach, trip generations are distributed based on trip length and control to forecast trip attractions are not applied.

5.3.4.2 Main Mode Split Model

The main mode split will determine the proportion of passenger trips using either private modes (car/taxi) or public modes (bus and minibus). A binary logit model will be applied based on the difference in modelled generalised travel cost between the two modes. The logit function gives the proportion of trips using public transport at a given difference in cost. An overview of the Main Mode Split model is given in Table 5-16.

Table 5-16 Main Mode Split Model Overview

Inputs	10a 8 9	Daily Production/Attraction Trip Matrices by Purpose and Car Availability Zonal matrix of highway generalised cost for CA and NCA trips by purpose Zonal matrix of public transport generalised cost for CA and NCA trips by purpose Observed Daily Person Main Mode split across screenlines
Methodology		Apply logit diversion curve to each zone pair to divide trips into private or public according to difference in journey cost
Outputs	10b	Daily Production/Attraction Trip Matrices by Purpose and Main Mode

The specific form of the main mode split model function employed in the CTS model is as follows:

$$P_{Pv} = \frac{1}{(1 + e^{((GC_{pt} - GC_{pv}) * a + b)})} \quad (5\text{-}2)$$

where:

P_{PV} = the probability of choosing private mode for any OD pair

GC_{PT} = generalised travel cost by public mode from origin to destination

GC_{PV} = generalised travel cost by private mode from origin to destination

a = slope parameter (sensitivity of curve)

b = mode constant (bias factor, negative = in favour of private modes)

The main mode split model calibration is somewhat constrained by the available data. Limited data is available from the household interview survey for car available households and taxi trips in which around 4,000 car/taxi trips were observed for all of Shenzhen. However this survey is insufficient to calibrate any meaningful relationship regarding mode choice (i.e. proportion choosing public transport at a given difference in travel cost) due to the small number of observations when disaggregated by zone and trip purpose category.

Our proposed methodology is to import model parameters (slope and constant) from elsewhere and then adjust the constant term (and retain the slope parameter) such that observed screenline crossings are represented correctly.

5.3.4.3 Peak Hour Model

The peak hour model is used to convert from daily trips (production/attraction format) to peak hour trips (origin/destination format) for assignment. For this purpose a series of sector-to-sector factors are applied to the 26 trip purpose / car availability categories. Initial factors were extracted from the home interview survey and are subject to refinement during the CTS model runs in order to reproduce observed screenline crossings.

Apart from the importance of the peak hour forecasts in rail system sizing, the peak hour assessment also determines the performance of the highway network which is used in the main mode split and sub-mode split model. Consequently, both the public transport and private transport peak hour models must be validated to an acceptable level. An overview of the approach to the peak hour forecasts is provided in Table 5-17.

Table 5-17 Peak Hour Model Overview

Inputs	10b	Daily Production/Attraction Trip Matrices by Purpose and Main Mode Initial sector to sector peak hour factors - from household survey data Observed daily and peak hour person/vehicle flows across screenlines Vehicle Occupancy factor for private modes
Methodology		Refine sector to sector peak hour factors to match flows
Outputs	11 12	AM / PM / Off-peak car and taxi vehicle trip matrices AM / PM / Off-peak public transport trip matrices
Issues		No data available for daily to peak hour rail factors

The peak hour periods are defined as follows:

- AM peak hour 08:00 – 09:00
- PM peak hour 17:30 – 18:30
- OP one hour (16 hour total – AM peak – PM peak) / 14

In model application, the daily flows are derived by calculation from the three 1 hour assignments as follows: AM + PM + 14*OP. Thus, model validation and application is undertaken at the AM, PM and Daily level. Off-peak validation (single hour) is not required.

Peak hour forecasts for the rail system are refined in the RDS model. In established rail systems, the rail system generally shows a higher peak hour factor than bus services. This higher factor is due to a number of related reasons:

- Rail is generally (more expensive and) used by a higher proportion of HBW trips which are made within the peak periods; and

- Rail is quicker and so more journeys can be started and completed within the peak hour.

5.3.4.4 Sub-Mode Split Model

The sub-mode split model parameters define the relationship between relative journey costs by mode and the proportion of trips using each mode. The output from the sub-mode split model is the proportion of public transport trips travelling by either (i) rail or (ii) other public transport modes. A 'binary' logit model will be applied in order to divide trips into rail or non-rail as this is the most basic choice that travellers make. Separate curves will be applied for short, medium and long trips.

Apart from the total public transport trip matrix, the basic inputs to the sub-mode split model include travel cost skim matrices taken from 'biased' assignments for rail and for non-rail preferred paths. For each O-D pair, the sub-mode split mode then allocates total trips to either the rail or non-rail mode based on the difference in costs.

The model parameters include the *slope* i.e. degree of sensitivity and *mode constant* i.e. bias constant which can be expressed in terms of minutes in favour of a particular mode. The specific form of the sub-mode split function employed in the PTM is as follows:

$$P_r = \frac{1}{(1 + e^{((GCn - GCr)*a - b)})} \quad (5\text{-}3)$$

where:

P_r = the probability of choosing rail mode for any OD pair

GC_n = generalised travel cost by non-rail modes from origin to destination

GC_r = generalised travel cost by rail modes from origin to destination

a = slope parameter

b = mode constant (positive = in favour of rail)

The parameters a and b are ideally calibrated based on observed data. For Hong Kong applications, a comprehensive household interview survey named the Travel Characteristics Survey (TCS) was undertaken in 1992. For cases with little survey data (or with no existing rail system such as Shenzhen) then imported values need to be used (subject to sensitivity tests). In Hong Kong our calibration showed a preference for rail for longer trips and for bus for shorter trips. As expected, shorter trips were more sensitive to differences in travel costs between rail and other public transport services.

Chapter 6

CONCLUSIONS AND RECOMMENDATIONS

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6.1 Simplified Models

It was agreed that both detailed and simplified models are required for transport planning purposes. It is difficult to define a degree of simplification since all model include simplified representations. Such models should deal with various policy effects and should produce results quickly for each new alternative studied. These results should be clearly intelligible to non-specialists. Input data should not demand expensive special-purpose surveys and should use generally available existing sources as far as possible. The interaction between the traffic components of the models and the environmental and land use characteristics of the area studied is clearly of vital importance and affects the evaluation of the utility of transport as a part of the urban fabric. It is suggested that accessibility could be developed to provide a consistent means of evaluating land use effects.

In order to discuss simplification, these themes need to be considered separately.

- The first involved a process of refinement, thinning out or generalisation of the conventional four-step modelling process.

- The second attempted to define a new family of models in which the travel and the transport supply are linked in a closed loop which automatically find its own equilibrium.

The latter type of "equilibrium" model is fundamentally better suited to the study of future changes but can suffer from lack of familiarity for most traffic engineers. However as traffic restraint ,Whether by congestion, or by artificially applied means, become increasing importance it may become necessary to adopt equilibrium models for this reason alone. The essential property of equilibrium models is their ability to represent internal and external interactions in a system involving numerous variables.

The importance in policy issues of identifying groups of the population who gain or lose by changes in the transport situation and the effect of the balance between public and private transport on such questions and on infrastructure planning mean that a considerable degree of disaggregation is inevitable in models used for strategic studies.

6.2 Four-step Models

In spite of their fundamental limitations, four-step models have been widely used for transport planning purposes. Their adaptation for strategic purposes depends upon the extent to which they can be simplified and still produce useful results, quite apart from the question of whether they are sufficiently responsive to changes in transport conditions. Taking the four steps individually the following points can be made:

- Trip Generation

It has been the practice to derive generation functions for individual towns from home interview surveys. This is and expensive process and there is considerable demand for generalised data for strategic purposes. Variation in these functions between cities can be considerable, even with allowance for SUCH FACTORS AS LEVEL OF CAR OWNERSHIP.

Examples of simplifications which have been adopted are the restriction of journey purpose to two categories or even to one category, the use of a regional rather than a detailed level of analysis, simplified techniques for deriving a future trip matrix from an existing one, and the derivation of average generation factors for suburban residential areas. A method being developed uses existing travel data for small number of zones and relates the aggregate travel patterns to land use planning without the use of a computer.

The overall criticism which affects all the above examples, however, is that trip generation is frequently not explicitly a function of the level of service provided by the transport system and this can therefore give rise to highly unrealistic conclusions (e.g. failure to predict increases in traffic when new roads are built). Attempts have been made to relate trip generation to level of service (or perhaps accessibility) but this is not a part of the basic model structure and inconsistencies can occur. However the theory referred to in Appendix I provides a systematic basis for such developments.

- Trip Distribution

The process of estimating the number of trips between pairs of zones has provided little scope for introducing effects of land use and transport system changes .By divorcing distribution from generation the full impact of new developments can be lost, in spite of the apparent advantage of being able to identify, say, the effect of a change in attraction in a given zone .The division of the conventional model into its four steps is the source of its weakness; it tends to lack feed-back from one stage to another. Iterative methods have been used to overcome this difficulty but then .

- Modal Split

The division of trips between the modes of transport available can be done before or after the distribution stage. In the former case the effect of transport system efficiency on mode choice is lost and in the latter case movements between zone pairs cannot normally be affected by mode characteristics. In urban situations where important changes is the modes used for certain journeys are likely, these difficulties present serious problems. Most members of the Group are seeking better information on the effect of mode characteristics on patronage, the incorporation of a sound relationship between choice of mode and route, and a balanced way of allowing for the interaction between land-use changes and (public) transport developments. Particular mention is made of the influence of fares, car park and other charges and of the need to ensure that generalised costs are consistent with assignments. In particular circumscribed cased some success has been achieved using tables of present modal split for a few sub-divisions of a town; also very simplified descriptions of level of service have been used to give broad indications for planning purposes. If there is a prospect of a "new" mode being added to the system the four-step process is particularly weak.

- Assignment

It is at this stage that the main effect of transport supply on demand is introduced into the four-step process but it is only by unusually powerful feed-back and reiteration procedures that allowance for this can be made adequate.

Thus the four-step model can only be made really satisfactory by an intimate inter-linking of its stages in a way that brings it close to a genuine equilibrium model . For the purposes of strategic planning this degree of complexity is not usually acceptable and in many cases such planning has employed very elementary components of the four-step process, the validity of which can only be regarded as satisfactory in particular limited circumstances.

6.3 Demand Supply Equilibrium Models

These models combine the four steps discussed above into a single model structure which includes the necessary feed0back connections and hence computes an equilibrium which satisfies all the functions describing the total transport system and its users. A variety of such models can be constructed using , for example, the DODOTRANS or RRLTAP systems of computer programmes. The basic theory behind such models and their relationship to the four-step type of model has been summarized in this report. A great deal more needs to be done to develop both the modelling concepts and the necessary input data but there are strong indications that the equilibrium class of model possesses the fundamental inter0linkages which should be characteristic of a tool suitable for broad strategic studies. If the equilibrium type of model is adopted, Various ways of simplifying it can be sued,. One example which has been tried is the ring0radial idealization of the network employed in CRISTAL. Future developments should include tests of simplification of all the functions include in the model structure so that important additions to the breadth of the factors studied (such as environmental effects) can be made without too unwieldy a result.

6.4 Land Use

It is important for strategic studies that the interaction between transport and land use should be represented. If only in simplified terms. For traffic planning purposes, it has commonly been the practice to take a land-use plan as an input and hence estimate the traffic generated: this can be misleading in the case of important changes in the transport system.

An example of the type o model which assists in the understanding of land-use/transport interaction uses an accessibility index which combines the various choices offered by a city with the ease of access to them in a function which can be evaluated on a zone-zone basis. Types of employment and recreation can be treated separately or combined to built up a picture of service provided and traffic resulting, It should be mentioned, however, that such traffic would not be subject to capacity constraints in the simple type of model envisaged.

Practical cases demand the minimizing of the number of variables to be considered. Typically an urban area might be described by its population, number of employed, number of employment opportunities and percentage of those which are tertiary. Comparison between results obtained from such a simplified picture and those from a full household survey show that the weighted error affecting traffic generation for the simpler model amounts to 10-20 percent. This might be acceptable for broad strategic purposes.

6.5 Public Transport

Urban transport planning is almost universally concerned at present with the need to transfer traffic from private cars to public transport, which may be of a novel form. The modelling of this process is thus a vital factor.

Estimation of future patronage form tables of current modal split can be used to give a rough estimate for strategic purposes but methods which include the effect of level of service are recommended wherever possible. A "pivot point" approach using an elasticity to a measure of level of service such as frequency can be simple and easy to apply.

The use of more complete generalised cost functions to describe public transport journeys can reflect the combined effects of a number of interacting parameters but tend to increase model complexity. Ways of minimizing this difficulty include:

- use of crow-fly distances;
- use of zone average speeds;
- combination of many trip purposes.

The choice of simplification must depend upon the purpose for which the model is to be used ,since for some strategic studies disaggregation (e.g. of trip purpose) is essential . Thus there is a need for a range of models for use by transport planners and the choice of model for each individual purpose is an area of work which has not yet been fully explored.

The need for public transport to meet the needs of particular sectors of the population (e.g. young, old, infirm, etc.) can override simple economic considerations and must be allowed for in the situation modelled.

6.6 Recommendations

The leading recommendations are summarized in the following items:

1) Simplified models facilitate the rapid analysis of many alternative transport policies and help the study of the sensitivity of forecasts to sources of uncertainty such as model parameters and external assumptions. Some models of this type exist and have been described in this report. They could be employed in some cases but considerable development is still desirable.

2) Equilibrium models provide the internal interactions necessary for studies in cases where important changes in the transport situation can be anticipated. Conventional four-step models are not well suited to such problems.

3) Where four-step models are employed for strategic studies it is desirable to integrate the computer programs so that the user can run the entire model in a single step. This facilitates rapid analysis and offer the possibility of using iterations to study changing conditions while maintaining consistency. Ordinary four-step models based on households can be simplified by using few types of household and fewer travel purposes. Household models are rather complicated and require home interview data. A new type of model based on traffic counts offers simplicity and results can serve strategic planning purposes.

4) It is essential that errors involved in each of the stages of the stages of the data

collection and modelling processes are clearly stated and the trade-off in the allocation of resources should be understood.

5) There is considerable demand for standardization of definitions and format in data collection so that data banks can be accumulated and accessed for many different purposes. This is not solely related to simplified models but the possibility of international co-operation in this field should be studied.

6) Since disaggergate modelling techniques are particularly promising for simplified models, priority should be given to the international exchange of data suitable for their estimation.

Chapter 7

REFERENCES

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REFERENCES

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APPENDIX

APPENDIX I GENERAL SHARE MODEL

The General Share Model (GSM) is defined as:

$V_{klmp} = \alpha(Y)\,\beta_k(Y)\,\gamma_{kl}(Y)\,\delta_{klm}(Y)\,{}^{*}klmp(Y)$

Where:

$Y = f(R, Z) = f(\underline{A}, \underline{a}, \underline{X}, \underline{w})$

Where α, β, δ, w are functions which meet the following Range Conditions for all values of Y:

$0 \leqslant \alpha(Y)$;

$0 \leqslant \beta_k \leqslant 1$, $\Sigma_k \beta_k(Y) = 1$;

$0 \leqslant R_{kl}(Y) \leqslant 1$, $\Sigma_l r_{kl}(Y) = 1$ for every k;

$0 \leqslant \delta_{klm}(Y) \leqslant 1$, $\Sigma_m \delta_{klm}(Y) = 1$ for every k, l;

$0 \leqslant w_{klmp}(Y) \leqslant 1$, $\Sigma_m w_{klmp}(Y) = 1$ for every k, l, m;

The Basic variables are :

V_T = total volume of trips (interzonal) in the region = $\alpha(Y)$

V_k = trip generation = total volume originating in zone k= $\beta_k(Y)\,V_T(Y)$

V_{kl} =trip distribution = volume going from zone k to zone l = $\gamma_{kl}(Y)\,V_k(Y)$

V_{klm} =modal split = volume going from zone k to zone l by mode m = $\delta_{klm}(Y)\ V_{kl}(Y)$

V_{klmp} =trip assignment = volume of trips going from zone k to zone l by mode m and path p = $w_{klmp}(Y)$ ^{V}klm (Y)

$\underline{A}$ =vector of variables describing the socio-economic activity system

a =vector of parameters applying to $\underline{A}$

$\underline{X}_{klmp}$ =sector of S level of service variables (i = 1,2 . . . S) describing the transportation system characteristics as experienced by trips from k to l by mode m and path p

$\underline{X}$ = $\underline{X}_{klmp}$ =set of all level of service characteristics for al paths of p of all modes in between all origins k and all destinations l

$\underline{X}^{1}$ =vector of parameters applying to $\underline{X}$

$^{R}klmp$ =f($\underline{X}$,$\underline{w}$) = combined effect of all level of service characteristics of all modes as they influence trips from k to l by mode m and path p –a "generalised cost"

$^{R}klmq,p$ = combined effect of all level of service characteristics of mode q as they influence trips from k to l by mode m and path p

Z =f($\underline{A}$,$\underline{a}$) = combined effect of all activity system characteristics

Y =f(Z,R) = combined effect of all activity system and level of service characteristics

Several basic properties of the GSM have been demonstrated:

- any explicit model ,of the form V= Ψ(Y) can be written as an equivalent GSM;
- any sequential implicit model ,of the form :

$V_k \;= б_1 (Y)$

$V_{kL} \;= б_2 (Y, V_k)$

$V \quad V_{klm} \;= б_3 (Y, V_{kl})$

$V_{klmp} \;= б_4 (Y, V_{klm})$

Can be written as an equivalengt GSM (provided it os internally consistent);

- the GSM can be wirtten either as an explicit form as given above or ad an equivalent internally-consistent sequential implicit form;

$V_T \;= \alpha (Y)$

$V_k \;= \beta_k (Y) \cdot V_t$

$V_{kl} \;= \gamma_{kl} (Y) \cdot V_k$

$V_{klm} \;= \delta_{klm} (Y) \cdot V_{kl}$

$V_{klmp} \;= w_{klmp} (Y) \cdot V_{klm}$

Thus ,as a conseuence of the above ,any explicit demand model can be written equivalently as a sequential implicit model ,and any internally-consistent sequential implicit model can be written equivalently as an explicit model.